Environment Canada
Inland Waters Directorate
executed for
Energy, Mines and Resources, Canada

Water Supply Constraints to Energy Development - Phase VII

Summary Report

July 1988

ACRES Acres International Limited

89-06172/

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1 - INTRODUCTION

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Inland Waters/Lands (IW/L), Environment Canada, sponsored by the Department of Energy, Mines and Resources, has progressively been developing a comprehensive capability for evaluating water supply constraints to energy development in Canada. This work, undertaken for IW/L by Acres International Limited (Acres), has now continued over seven phases. The present Phase VII Summary Report and corresponding User's Manual follow the Phase I, II, III, IV, V and VI reports and manuals of August 1982, May 1983, July 1984, July 1985, July 1986 and April 1987, respectively (References 1, 2, 3, 4, 5 and 6).

1.1 - Background

The assessment of present and projected availability of water for multipurpose use in the country, particularly in the context of interprovincial or international water concerns, is an important activity of the federal government, undertaken by IW/L. It was determined in 1981 that the potential impact of large expansions in the energy sector on water use and availability required an assessment of water supply constraints to energy development, leading to initiation of this project.

The original study identified and documented proposed energy developments, together with corresponding water quantity and quality aspects (Phase I). This was followed by initial development of a Water Use Forecasting Model (WUFM), subsequently denoted the Water Use Analysis Model (WUAM), including data base preparation and trial evaluations for potentially critical river basins in the prairie provinces (Phase II). A significant enhancement to the WUAM in the area of irrigation water use evaluation was then undertaken, again including data base preparation and trial evaluations (Phase III).

At this point a major expansion of the prepared data base, to cover the entire prairie provinces portion of the Saskatchewan-Nelson River basin, was effected, and future development scenarios in various sub-basins were analyzed (Phase IV). Additional enhancements to the WUAM, including a capability for explicit modeling of reservoir operations, as well as further data base improvements and scenario evaluations, were then made (Phase V). This was followed by the incorporation of graphics capabilities into the WUAM, the initial development of a model enhancement for evaluation of electric energy water use, and several other model improvements aimed at making the model more comprehensive, together with data base updates and scenario evaluations (Phase VI).

The present work (Phase VII) has included further development of the graphics capabilities, enhancements to the industrial water use and demand/price analysis routines, and a number of data processing improvements. Data base expansions and scenario evaluations have also been undertaken.

1.2 - Objectives of Phase VII

The objectives of the present phase of the work were to

- effect several data handling improvements

- revise the industrial water use forecasting routine and data for application on a provincial basis

- expand the graphics capabilities of the model

- provide for analysis of annual variations in evapotranspiration for irrigation water use estimates

- incorporate an enhanced industrial water demand/price routine and corresponding data

- incorporate details of additional reservoirs into the prepared data base for explicit modeling of their operations

- apply the enhanced model and data base to the evaluation of development scenarios for the Saskatchewan River basin, including an extension of the previous forecasting horizon to the year 2011.

Another objective of Phase VII had been to provide an electrical energy stacking routine to complement the Electric Energy Water Use Submodel (EEWUS) developed in the previous phase. However, funding for this work did not become available.

1.3 - Work Plan

The work plan followed during Phase VII was comprised of the following elements

- model and data base enhancements relating to data processing, industrial water use and demand/price analyses, explicit simulation of additional reservoirs, and graphics capabilities

- applications including program testing and scenario formulation, data compilation and extension, and evaluations

- report preparation including progress reports, and draft and final Summary Report and User's Manual

- administration of project services and disbursements.

The model and data base enhancements of this phase are presented in Section 2 of this Summary Report. Section 3 then details the model applications, including scenario assumptions and evaluation results. A summary and conclusions are given in Section 4, while recommendations for future work are included in Section 5. The companion Phase VII User's Manual is a fully comprehensive and updated reference for model use.

2 - MODEL AND DATA BASE ENHANCEMENTS

2 - MODEL AND DATA BASE ENHANCEMENTS

2.1 - Data Processing

2.1.1 - Potential Evapotranspiration Time Series

The model was modified to allow for the input and analysis of monthly reference evapotranspiration data, over a period of record compatible with the precipitation record. This modification permits the user to assess the impact of the annual variability of evapotranspiration on irrigation water demands.

Before an irrigation simulation is performed, the model determines the common duration of the precipitation and evapotranspiration data records. Only the overlapping portion of the records is used in the simulation.

Annual evapotranspiration data were not prepared in this phase. However, the data file has been modified by maintaining the present mean monthly values constant over the period of record.

2.1.2 - Conversion of Natural Streamflow Data

The model was converted to utilize natural streamflow data prepared in metric units. The current data base was also modified to convert the existing streamflow files from imperial units to metric units.

A new utility module, identified as MODULE 6B, was written to convert data files. It is an interactive program which reads a streamflow data file and converts the units from cubic feet per second to cubic meters per second.

The natural streamflow, boundary flow and regulated streamflow files were converted to metric units as part of the task.

The regulated flow file is a new feature of the model which allows the user to override the local inflow to a node, calculated in MODULE 6. The effects of reservoirs can therefore be approximated without direct modeling of their characteristics.

2.1.3 - Creation of Output Flow Files

A new utility module, identified as MODULE 6C, was written to produce nodal output files for use as input files in subsequent subnetwork analyses. The module is an interactive routine which reads the entire OUTFLOWS.DAT data file and allows the user to generate separate streamflow files for selected nodes.

The module converts units from millon cubic meters per month to cubic meters per second. A different node name from the original must be used to ensure that the user is conscious of the new contents of the file.

Identification lines are added to the end of the simulated outflows file as follows.

```
NOTE:  SIMULATED OUTFLOWS
YEAR:  x x x                        |  Forecast Year
RUN:   x x x x x x x x x            |  Simulated Run Description
       x x x x x x x x x            |
       x x x x x x x x x            |
```

In the modeling of a network, upstream nodes can be affected by downstream reservoir demands, irrigation area demands, apportionment demands and cutback procedures. When selecting a subnetwork for analysis, using simulated outflow files, the user must be aware of potential problems which could arise. The impact of subnetwork model adjustments on upstream nodes may be masked by the use of previously simulated outflows at the upstream end of the network.

This would be the case, for example, if a user were to model developments resulting in flows farther downstream which might violate apportionment agreements. The WUAM would only attempt to cut back demand and utilize reservoirs in the subnetwork to satisfy the boundary flow requirements. Reservoirs and demands upstream of the subnetwork would be unaffected in this process. However, in the prototype they would actually be available to satisfy apportionment. The subnetwork model would, therefore, ignore effects outside of the subnetwork while overestimating the impact within the subnetwork.

2.1.4 - Data File Identification Lines

All data files now allow the user to append an unlimited number of identification lines to the end of the file. This allows for internal documentation of the large number of input files currently accessed by the WUAM. The lines are not read or printed but will allow for the storage of relevant information such as the source of the file, date of data acquisition and any specific comments on the derivation of the data.

Identification lines are also used in the creation of the simulated outflows file discussed in Section 2.1.3. In this case, the module places several lines at the end of the file which would not be read by the WUAM during later simulation runs. Other data files have not been labelled using the identification lines as part of this phase.

2.2 - Industrial Water Use Analysis

2.2.1 - Revised Growth Forecast Data

The previous, regionally-based, industrial growth forecast data has been replaced by provincial industrial growth forecasts prepared by Informetrica Limited (Reference 11). Alternative forecasts are not included in the data base now but could be incorporated in the future.

The Informetrica forecasts give average annual rates of growth in gross domestic product on a sectoral and provincial basis for four time periods: 1981 to 1986, 1987 to 1991, 1992 to 1996, and 1997 to 2005. The format of the forecast data file allows the user to select the number and length of the forecast periods depending on the data available. The 30 basic industrial sectors used by the WUAM and the sectors covered by the Informetrica forecasts are shown in Table 2.1. The following assumptions were made where the sectors used by the WUAM were not identical to those used by Informetrica.

- WUAM uses a single 'mineral fuels' sector which includes both the 'petroleum and gas' and 'coal' sectors used by Informetrica. In the model, the forecasts for the petroleum and gas industry have been taken as being representative of the total mineral fuels sector.

- The 'primary metals iron' and 'primary metals, other' sectors in WUAM have both been assigned the Informetrica forecast for primary metals.

- The 'textiles' sector in WUAM includes the 'textiles' and 'knitting and cloth' sectors used by Informetrica. In this case, the 'textiles' industry will have a larger water use so its forecast has been used as the WUAM sector forecast.

TABLE 2.1

LIST OF INDUSTRIAL SECTORS

Informetrica Sectors	WUAM Sectors
Agriculture	1 Agriculture
Forestry	2 Forestry
Fishing and Trapping	
Resource Extraction	
- Metals	3 Metal Mines
- Coal	
- Petroleum and Gas	4 Mineral Fuels
- Nonmetals	5 Nonmetal Mines
- Mining Services	
Manufacturing	
- Durables	
- Wood	6 Wood
- Furniture	7 Furniture
- Primary Metals	8 Primary Metals, Iron
	9 Primary Metals, Other
- Metal Fabricating	10 Metal Fabricating
- Machinery	11 Machinery
- Transportation Equipment	12 Transportation Equipment
- Electrical Products	13 Electrical Products
- Nonmetallic Minerals	14 Nonmetallic Minerals
- Nondurables	
- Food and Beverages	15 Food and Beverages
- Tobacco	16 Tobacco
- Rubber and Plastics	17 Rubber and Plastics
- Leather	18 Leather
- Textiles	19 Textiles
- Knitting and Cloth	
- Pulp and Paper	20 Paper
- Printing and Publishing	21 Printing
- Petroleum and Coal	22 Petroleum and Coal
- Chemicals	23 Chemicals
- Miscellaneous	24 Miscellaneous
Construction	25 Construction
Transportation	26 Transportation
Storage	
Communication	

Table 2.1
List of Industrial Sectors - 2

Informetrica Sectors	WUAM Sectors
Utilities	27 Electric Power 28 Other Utilities
Trade	29 Trade
Finance, Insurance and Real Estate	
Services - Education - Health and Welfare - Private Commercial	30 Other
Administration	

Note: WUAM sectors are listed next to the Informetrica sector whose forecast is adopted for incorporation into the data base.

- 'Transportation', 'storage' and 'communication' sectors used by Informetrica are all included in the 'transportation' sector used by WUAM. In this case, the transportation sector has larger water use than storage or communications so its forecast has been adopted.

- The Informetrica forecast for 'utilities' has been assumed to be representative of both 'electric power' and 'other utilities' sectors in the WUAM. However, for major electric power developments specific water use rates are input directly and separately into the model.

- The 'other' sector used by the WUAM includes all other Informetrica sectors, all of which will have small water use requirements. The Informetrica services forecast is used for the WUAM 'other' sector and is assumed to be applicable to the 'mining services', 'finance', 'insurance and real estate', 'education', 'health and welfare', 'private commercial' and 'administration' sectors.

For scenario years beyond 2005, the Informetrica forecast for 1997 to 2005 has been adopted as representative of the long-term growth in the industrial sectors. Growth to any given scenario year is found by accumulating the growth rates from the base year 1981 to the scenario year.

2.2.2 - Revised Impact Matrix Data

The input/output matrices describe the interrelationships between the sectors of the economy. The model uses the matrices to estimate the increased water demand caused by an increase in 'final demand'. Prior to this phase, there were two types of matrices contained in the model

- inverse intraregional matrices, which express the impacts between sectors within a specific economic region for a given vector of final demand

- interregional trade matrices, which express the sectoral linkages between economic regions.

In the current phase, the five economic regions used in earlier phases have been disaggregated to match provincial boundaries. Revised versions of the intraregional matrices were received from IW/L and incorporated in the model.

After discussion with IW/L, it was decided to leave the interregional matrices out of the model at this time. The model was adjusted so that only the intraregional matrix is now used for analyzing the effect of sectoral economic investments in a region. Growth forecast data is assumed to implicitly include the intra- and inter-regional impacts so that the matrices are not required in preparing sectoral forecasts.

The inverse intraregional matrices were used to estimate the related sector output values for inclusion in the data base. The final demand for each sector was extracted from data supplied by IW/L. The sector output was then calculated by multiplying the final demand vector by the inverse intraregional matrix. The sector output values were escalated to the 1981 base year expressed in 1974 dollars using factors provided by IW/L.

2.3 - Industrial Water Demand/Price Analysis

The WUAM allows the user to evaluate the impact of water price increases on the annual intake volume of both the industrial and municipal sectors. This routine was originally incorporated into the model as a part of Phase V. In the routine, the user specifies a sectoral price change. The impact of the change is then defined through the use of a series of user-supplied water demand curves which plot price versus water quantity.

In this phase, the industrial water demand/price routine has been improved by the addition of an enhanced routine based on recent research. Development of this additional option is described in the following two subsections.

2.3.1 - Formulation of Alternative Methodology and Data

Renzetti (References 15 and 16) developed expressions for the water demand using regression analysis of data collected in the 1981 Industrial Water Use Survey. These equations are presented for each province and several key manufacturing sectors.

For all provinces but British Columbia, the volume of water intake is related to the price of water and the level of output by a family of equations (Reference 15).

$$Ln\ (Q_{in}) = a_o + a_1 Ln(P_{in}) + a_2 Ln(Q) \tag{1}$$

where,

Q_{in} = annual intake volume (m^3)
P_{in} = price (\$/m^3)
Q = output variable
a_i = regression coefficients.

The output variable used in the equations is the total annual employee person-hours. For applications in the WUAM, the equations are transformed into an exponential format, the output term is dropped and the ratio between the water intake at price P_{in} and an escalated price nP_{in} then becomes

$$\frac{(Q_{in})'}{(Q_{in})} = \frac{(nP_{in})^{a_1}}{(P_{in})^{a_1}}$$

where,

$(Q_{in})'$ = annual volume intake after price escalation
(Q_{in}) = annual volume intake at price (P_{in})
n = price escalation factor.

The effect of a price escalation of 'n' times is then estimated by the following ratio.

$$\frac{(Q_{in})'}{(Q_{in})} = n^{a_1} \qquad (2)$$

Note that price and the other variables used in Equation 1 are no longer required when estimating the effect on water intake. The regression coefficient a_1 is an expression of the elasticity of the intake volume to changes in price.

In the case of the province of British Columbia, Renzetti gives a slightly different form of Equation 1 (Reference 16).

$$L_n(Q_{in}) = a_o + a_1P_{in} + a_2Q \qquad (3)$$

If the effect of price changes is evaluated in a similar fashion to the other provinces, the following relationship results.

$$\frac{(Q_{in})'}{Q_{in}} = e^{a_1P_{in}(n-1)} \qquad (4)$$

The application of Equation 4 is slightly more difficult than Equation 2 in that the price of a unit of water must be determined and applied in the solution. However, Reference 16 also provides estimates of the price elasticity of water intake demand for British Columbia which can be used directly in the estimation of the change of water intake with changes in price. The elasticity given can be expressed mathematically as

$$\frac{dQ_{in}}{dP_{in}} = E\,\frac{Q_{in}}{P_{in}}$$

where, E = price elasticity

This equation can be used to evaluate the effect of a price escalation as follows.

If $Q_{in}' = Q_{in} + \Delta Q_{in}$

and $n = \dfrac{P_{in} + \Delta P_{in}}{P_{in}}$

$$\Delta P_{in} = P_{in}\,(n-1)$$

then, $\Delta Q_{in} = E\,\dfrac{Q_{in}}{P_{in}}\,P_{in}(n-1)$

and $Q_{in}' = Q_{in} + EQ_{in}(n-1)$ (5)

Equation 5 can be used to evaluate the affect of a price escalation on water intake and is analogous to Equation 2 for the other provinces.

In order to accommodate the analysis of price changes in all ten provinces, the WUAM now provides the user the option of three methods.

1 - The Price Curves Method: this is the original method where the user defines the relationship between price and demand.

2 - The Price Coefficients Method: this is the method based on Reference 15 which uses Equation 2 to estimate the effect of price on demand.

3 - The Price Elasticity Method: this is the method based on Reference 16 which uses Equation 5.

The estimation equations (2) or (5) are used in the following approach to modeling.

(a) The user defines the regression coefficient a_1 or the elasticity E based on analytical findings, depending on whether Method 2 or 3 is selected.

(b) The user specifies the sector in which the effect of a price increase is to be investigated and the multiplier representing the future price increase n.

(c) Within the model, the effect of the price increase on the water intake is estimated from either Equation 2 or 5.

(d) Again within the model, the effect of price change is applied to the appropriate industrial sector for each network node in the region.

The above approach is similar to the previously developed routine; the major difference being the inclusion of an equation in place of the user-supplied curves. The previous water price/demand routine has been retained in the model, in the event that a user wishes to define a demand curve outside of the available expressions in the model. This will also allow for modeling the effects of price if an alternate approach to the formulation of the demand curve is desired.

2.3.2 - Incorporation into the WUAM

An additional data file has been prepared, giving values of the appropriate regression coefficients from Reference 15 for nine provinces and the price elasticity from Reference 16 for British Columbia. The sectors considered in the development of the demand/price equations do not correspond directly to all of the 30 sectors currently used in the WUAM. Therefore, for incorporation of the results of References 15 and 16 into the WUAM, the available equations have been applied to related sectors where possible. Table 2.2 shows the sectors represented by a Standard Industrial Classification (SIC) number, used in References 15 and 16, corresponding to each of the sectors used in the WUAM.

Equations are not available for all of the sectors used in the WUAM. Therefore, where possible the available equations are applied to other sectors to complete the data set for demonstration purposes. References 15 and 16 have dealt solely with manufacturing industries. While equations for similar or related industries have been used to complete the data set for manufacturing industries in the WUAM, this approach is not considered to be valid for the other nonmanufacturing industries. Therefore, no equations have been included for the primary and resource extraction industries or the 'construction', 'transportation', 'trade', 'utilities' and 'other' industries.

The two new industrial pricing algorithms were added as an option to the original water pricing method in the model. The original

TABLE 2.2

WATER PRICE/DEMAND EQUATIONS - COMPARISON OF SIC SECTORS TO WUAM SECTORS

WUAM Sector	BC	Alta	Sask	Man	Ont	Que	NB	NS	PEI	Nfld
1										
2										
3										
4										
5										
6	10	10	10	10	10	10	10	10	10	10
7	10	10	10	10	10	10	10	10	10	-
8	16	16	16	16	16	16	16	16	-	-
9	16	18	-	18	18	18	18	18	-	-
10	16	18	-	18	18	18	18	18	-	-
11	25	25	-		25	25	25	25	-	25
12	25	26	-		25	25	26	26	-	26
13	27	27	-	27	27	27	27	27	-	27
14	32	32	32	28	32	32	32	32	-	32
15	29	29	29	29	29	29	29	29	-	29
16	29	29	29	29	29	29	29	29	-	29
17	30	30	30	30	30	30	30	30	-	30
18	-	31	31	31	31	-	31	31	-	31
19	32	32	32	32	32	32	32	32	-	32
20	-	33	33	33	33	-	33	33	-	33
21	35	35	35	35	35	35	35	35	-	35
22	36	36	36	36	36	36	36	36	-	36
23	37	37	37	37	37	37	37	37	-	37
24	-	39	-	39	-	-	-	-	-	-
25										
26										
27										
28										
29										
30										

method is now identified as the curves method while the new algorithms are identified as the price coefficients and price elasticity methods. The user may choose the method to be applied for a particular simulation.

2.3.3 - Sample Application of Water Demand/Price Analysis

The WUAM model was used, with a standardized test data set, to demonstrate the effect of a price change on industrial water use.

The test data set is presented in the program users manual to illustrate typical data and output file structure and content. It consists of a total of eight nodes which utilize a broad cross section of the features of the model. The upstream node is a reservoir while the downstream end of the network represents a provincial boundary. Two tributaries to the principal stream are included. The network includes irrigation, industrial, domestic, livestock and diversion demands.

The 'Price Coefficients' method was used with a doubling of the price of water to industrial users. The effect of the price increase on the distribution of water use among competing demands in the basin is as follows.

	Base Case Without Price Change		Test Case With Price Change		Change	
Used	Intake (Mm^3)	Consumption (Mm^3)	Intake (Mm^3)	Consumption (Mm^3)	Intake %	Consumption %
Domestic	20.47	6.35	20.47	6.35	0	0
Livestock	9.35	8.14	9.35	8.14	0	0
Industrial	12.88	9.61	10.57	7.91	-17.9	-17.7
Energy Projects	1.06	0.26	1.06	0.26	0	0

	Base Case Without Price Change		Test Case With Price Change		Change	
Used	Intake (Mm^3)	Consumption (Mm^3)	Intake (Mm^3)	Consumption (Mm^3)	Intake %	Consumption %
Irrigation	140.8	88.8	140.8	88.8	0	0
Generation	10.8	10.8	10.8	10.8	0	0
Total	195.4	124	193.1	122.3	-1.2	-1.3

As shown here, the water demand/price analysis affects only the industrial water use. In the case tested a 200% increase in price results in a 17.9% decrease in industrial water demand and a decrease of 1.2% in total basin water demand.

The distribution of the impact among the various industrial sectors is not uniform and is a function of the relative magnitude of the coefficients obtained from the regression analysis given by Renzetti[15]. A comparison of the intake before and after the price increase is as follows.

No.	Sector	Base Case Without Price Change (Mm^3)	Test Case With Price Change (Mm^3)	Change %
1	Agriculture	0	0	0
2	Forestry	0.002	0.002	0
3	Metal Mines	0	0	0
4	Mineral Fuels	4.295	4.295	0
5	Non Metal Mines	0	0	0
6	Food & Beverages	0.603	0.444	-26.4
7	Tobacco	0	0	0
8	Rubber & Plastics	0	0	0
9	Leather	0.004	0.002	-50.0
10	Textiles	0	0	0
11	Wood	0	0	0
12	Furniture	0.010	0.009	-10.0
13	Paper	0	0	0
14	Printing	0.010	0.004	-60.0
15	Primary Metals - Iron	0	0	0
16	Primary Metals - Other	0	0	0

No.	Sector	Base Case Without Price Change (Mm^3)	Test Case With Price Change (Mm^3)	Change %
17	Metal Fabricating	0	0	0
18	Machinery	0.123	0.069	-43.9
19	Trans. Equipment	0	0	0
20	Electrical Products	0.197	0.099	-49.7
21	Non Metal Minerals	0.111	0.081	-27.0
22	Petroleum & Coal	0.018	0.014	-22.2
23	Chemicals	7.48	5.528	-26.1
24	Misc. Manufacturer	0.033	0.025	-24.2
25	Construction	0	0	0
26	Transportation	0	0	0
27	Electric Power	0	0	0
28	Other Utilities	0	0	0
29	Trade	0	0	0
30	Other	0	0	0
		12.88	10.57	-17.9

Note that the primary industries such as forestry, metal mines and mineral fuels and the service industries are not affected by the price change. Coefficients for these sectors were not available from the available reference report for use in the model.

The change in water demand is achieved in the model while still accepting the projected industrial growth. This implies that industries are capable of reducing water demand while simultaneously increasing production. In practice this may require a change in the process used in some industries or their replacement by newer more water efficient producers.

If pricing is a constraint to the availability of water for industrial users, the actual growth achieved may be less than the projected growth. A change in the price of water in one region may result in a lower growth rate in that region while other regions with a static price inflation would experience a more rapid growth rate. Therefore, the selected industrial growth forecast should be based on an appropriate water pricing scenario so that the forecasts are consistent.

2.4 - St. Mary and Waterton Reservoirs

2.4.1 - Physical and Operational Characteristics

The St. Mary and Waterton reservoirs were incorporated into the WUAM for explicit modeling of their operations in this phase. This task follows development of the reservoir routine and the inclusion of the Lake Diefenbaker, Dickson and Oldman reservoirs in previous phases. The reservoirs were incorporated using the procedures and methodology developed in earlier phases.

The St. Mary and Waterton reservoirs are important for the assessment of supply deficits caused by major irrigation demands in the South Saskatchewan River basin.

The Waterton reservoir was completed in 1964 to control the waters of the Waterton River and divert flows to the St. Mary project for irrigation purposes. Flows are diverted from the reservoir to the Belly River. A weir on the Belly River in turn diverts water to the St. Mary reservoir farther to the east.

The St. Mary reservoir was completed in 1951 to supply major irrigation and some municipal demands in southern Alberta. The Waterton, Belly and St. Mary rivers are the principle tributaries to the St. Mary reservoir. The former two rivers are diverted through the canal system noted above. Demands are supplied from the St. Mary reservoir by diversion to the St. Mary Ridge canal, which extends from the reservoir to supply the St. Mary River, Magrath, Raymond and Taber Irrigation Districts.

The United, Mountain View, Leavitt and Aetna Irrigation Districts, between Waterton and St. Mary reservoirs, are supplied from the Belly River.

The Waterton and St. Mary reservoirs are linked by the diversion canal, with all supply points to the irrigation districts coming from either the canal or from the Belly River. The water in the Belly River is diverted to supply the St. Mary reservoir as well as the local irrigation districts.

The St. Mary and Waterton reservoirs are operated in unison each year, with the timing and amount of drawdown in each being similar. The rivers are considered to be well regulated, and the capacity of the canal linking the reservoirs is large enough so that the parallel operation is maintained.

2.4.2 - Representation for Modeling Purposes

For modeling purposes, the Waterton and St. Mary reservoirs have been combined into a single composite reservoir with inflows from the Waterton, Belly and St. Mary rivers supplied directly to it.

The Waterton/St. Mary reservoir node replaces the node representing the three rivers added last year as part of the modeling of the Oldman reservoir.

The data required for modeling the reservoirs includes the

- full supply and minimum supply levels
- area/volume/elevation curves
- minimum, maximum and target monthly outflows
- upper and lower operational rule curves
- open water evaporation and precipitation.

The data describing the physical characteristics of the reservoirs was provided by Alberta Environment. The composite storage curve was created by adding the individual storage curves using an elevation scale ranging from 0% at the low supply level to 100% at the full supply level. This ensures that the available storage is distributed through the depth of the composite reservoir in a similar fashion to the prototype reservoirs. An artificial elevation scale of 0 to 25 m was assumed to represent the reservoir level, as shown in Table 2.3 and Figure 2.1.

The surface area of the composite reservoir was set equal to the sum of the individual reservoir areas at the full supply level. The remainder of the area/elevation curve was then calculated from the composite storage curve.

For interpretation of results, the composite stage storage curve may be disaggregated for any known storage to give the level in each of the two reservoirs as illustrated in Figure 2.1.

Minimum releases at the Waterton and St. Mary reservoirs were given by Alberta Environment as a riparian flow of 0.85 m^3/s at each. Not all of the water in the Belly River is diverted to the St. Mary reservoir. Water is also discharged over the weir to continue along the Belly River, flowing into the Oldman River downstream. The target reservoir releases are used to discharge the excess flows from the composite reservoir so that the remaining flow will simulate the actual contribution of the Belly River to the St. Mary reservoir. In the case of the minimum release, the riparian flows required on the Waterton and St. Mary rivers were added to the recorded minimum monthly flows on the Belly River downstream of the United Irrigation District (UID). The minimum flows were selected from natural flow records in References 7 and 10.

TABLE 2.3

WATERTON/ST. MARY COMPOSITE RESERVOIR - ELEVATION AREA VOLUME DATA

Composite Reservoir Elevation (m)	Area (km^2)	Volume (Mm^3)
0.0	7.3	70.9
2.5	7.9	88.8
5.0	9.2	108.8
7.5	11.3	132.9
10.0	14.2	162.7
12.5	17.9	200.2
15.0	22.3	247.3
17.5	27.5	305.7
20.0	33.5	377.3
22.5	40.2	464.0
25.0	47.7	567.5

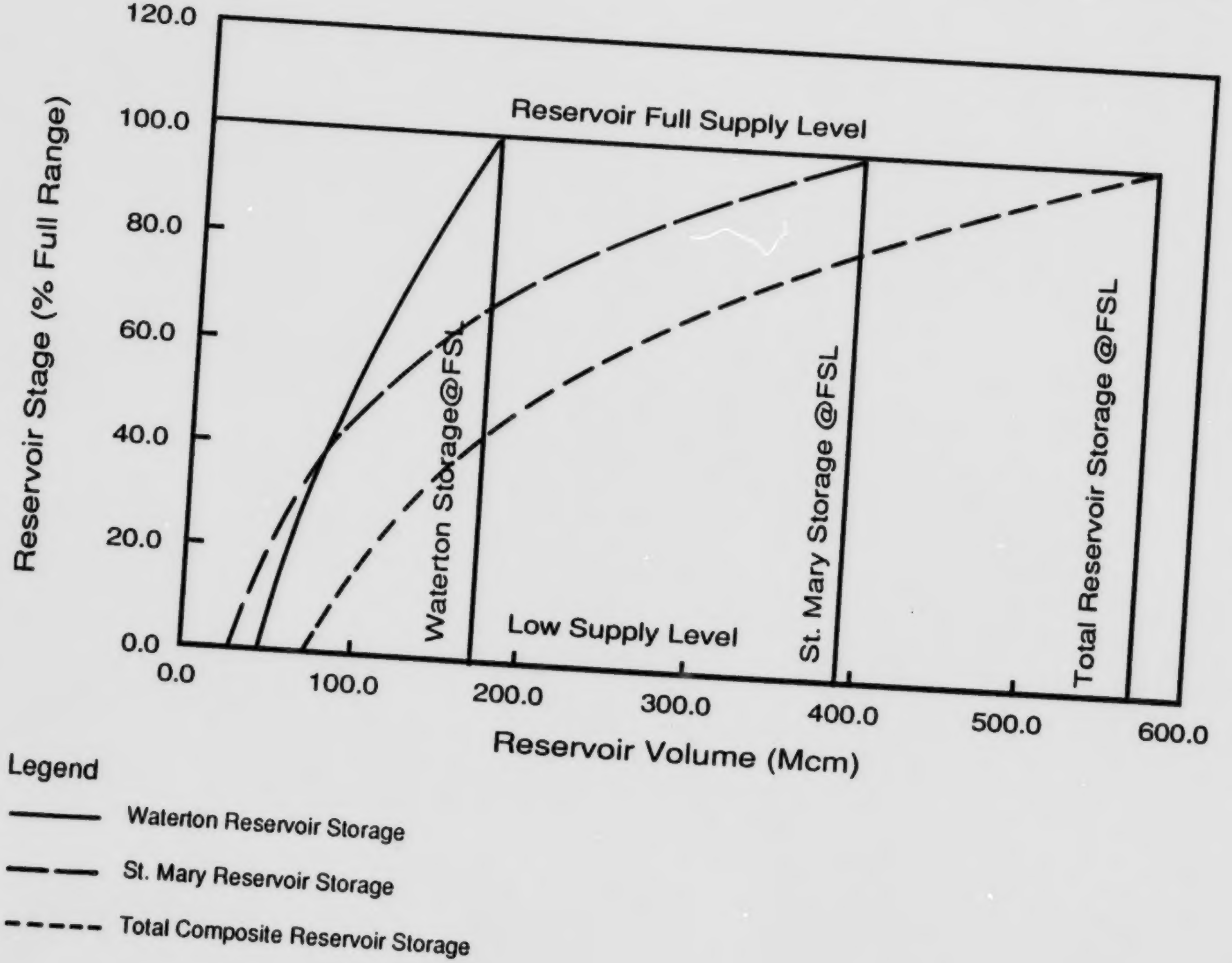


Figure 2.1

Waterton/St. Mary Reservoir Storage Curves

The target reservoir release was estimated by adding the average monthly flows on the Waterton and St. Mary rivers downstream of the reservoirs to the average monthly flows in the Belly River downstream of the UID.

In this approach, excess flows will always be released from the reservoir so that the average total outflow will be representative of that which actually occurs. However, because of variations in the natural flows in the Belly River and the amount of water diverted to the St. Mary reservoir, the use of target outflows will mask some details of the operation of the system. The approach selected, with a composite reservoir and target outflows, is considered to be conservative with the total errors being small given the relative volume of flow on the three rivers. The Belly River is the smallest of the three tributaries and a significant portion of its total annual volume is diverted to the St. Mary reservoir or to the other irrigation districts in the area. In some months, there is a net addition of water to the Belly River from the Waterton reservoir.

In dry years, the target outflow will tend to drain the composite reservoir slightly earlier than the actual case and, conversely in wet years, the reservoir will fill more quickly. This behavior is conservative but is considered to be acceptable given the purpose of the WUAM.

The maximum reservoir release was estimated as the total bankfull discharge on the Waterton, St. Mary and Belly rivers. The bankfull discharges were estimated from data given in Reference 12.

The selected minimum, target and maximum reservoir releases are summarized in Table 2.4.

The upper and lower rule curve levels were found by determining maximum and minimum composite reservoir storage for the period of

TABLE 2.4

WATERTON/ST. MARY COMPOSITE RESERVOIR - RESERVOIR RELEASES
(m^3/s)

Month	Minimum	Target	Maximum
January	2.3	9.5	895
February	2.5	9.5	895
March	2.6	17.4	895
April	2.5	26.0	895
May	2.7	82.9	895
June	3.8	112.4	895
July	2.9	41.8	895
August	2.6	19.8	895
September	2.3	21.7	895
October	2.1	18.5	895
November	2.3	14.6	895
December	2.6	19.3	895
Average	2.6	10.8	895

record given in References 7 and 10. The maximum and minimum storages for the key irrigation months of June, July and August were plotted and tested to ensure that no significant changes in reservoir operation have occurred over the period of record. The resulting monthly rule curve levels are given in Table 2.5.

Evaporation and precipitation values were available from the South Saskatchewan River basin natural flows study (Reference 7).

2.4.3 - Data Base Modifications

Reservoir data was incorporated in the data base files.

The inflow files to the new reservoir node were created by taking the sum of the natural streamflows at Gauges 05AD028, 05AD002 and 05AE006 on the Waterton, Belly and St. Mary rivers respectively. For Gauge 05AD028, natural streamflows were not available and a proration of flows at the adjacent Gauge 05AD002 was carried out to find the required natural flows, using a drainage area factor of 1.3471. Regulation of St. Mary River flows in the United States and the effect of apportionment at the international boundary were modeled through the application of a Prairie Provinces Water Board (PPWB) K-file to the natural streamflow file to obtain the regulated streamflow upstream of the reservoir. The 'K-files' were prepared by the PPWB in a 1982 Water Demand Study to indicate the effect that streamflow regulation has on monthly streamflow records.

2.5 - Interactive Graphics

Interactive graphics were first incorporated in the model in Phase VI to depict key information and allow the user to examine results rapidly, interact with the model to select the visual representation of the results and produce hard copy versions of

TABLE 2.5

WATERTON/ST. MARY COMPOSITE RESERVOIR -
RULE CURVES

Month	Upper Rule Curve Level (m)	Upper Rule Curve Storage	Lower Rule Curve Level (m)	Lower Rule Curve Storage
January	22.5	456.4	16.1	269.8
February	22.5	456.7	16.4	274.7
March	22.5	455.7	17.0	288.8
April	23.1	481.6	19.0	339.6
May	24.1	532.8	19.7	357.6
June	24.3	546.1	19.5	353.5
July	24.2	538.3	15.2	251.6
August	23.7	513.9	13.0	211.3
September	23.1	482.8	13.6	222.1
October	22.9	473.9	13.5	220.0
November	22.6	462.2	15.2	250.1
December	22.5	458.5	15.6	259.7

the graphics. The graphics routine accesses various WUAM files required to obtain the data requested by the user.

In this phase, seven additional graphics options have been added to the model and the plotting program was restructured into a series of menus from the previous single menu approach. Restructuring of the program was required to accommodate the number of graphics options now available and also allows the user to define the output device once rather than for each plot.

With the addition of seven graphics options in this phase a total of twenty-nine plots can be produced for any given analysis. The graphics capabilities added in this phase are

Node results - streamflow time series
- irrigation time series
- boundary flow time series
- energy time series

Reservoir results - elevation frequency summary
- release frequency summary

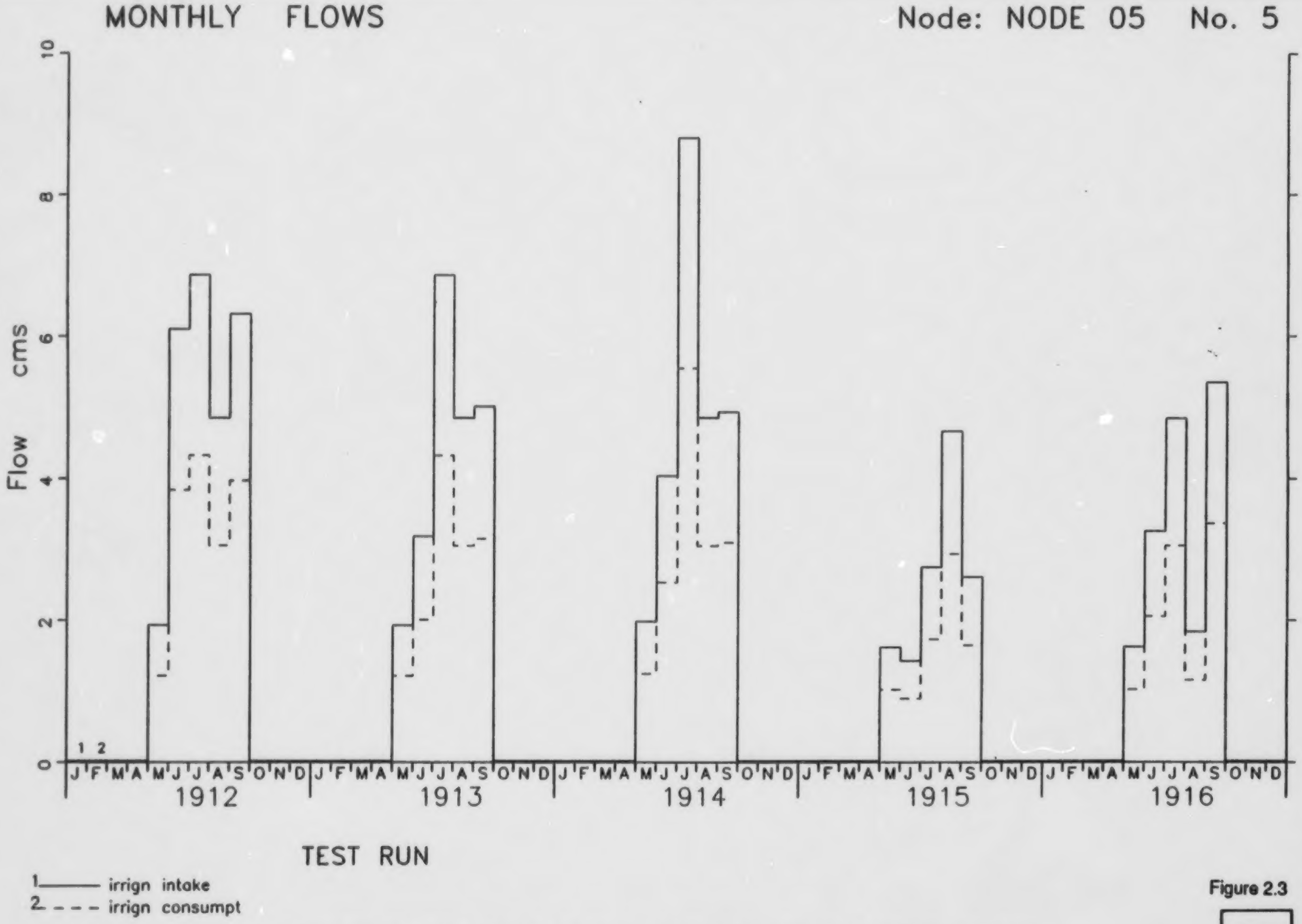
Irrigation area results - demand time series.

The features and utilization of each of these plots are discussed in the following paragraphs.

(a) Node Results: Streamflow Time Series

This plot is a presentation of the simulated and actual streamflows at a node in a time series bar chart format as shown in Figure 2.2.

The user selects which nodes are to be plotted and the graph is then automatically scaled.

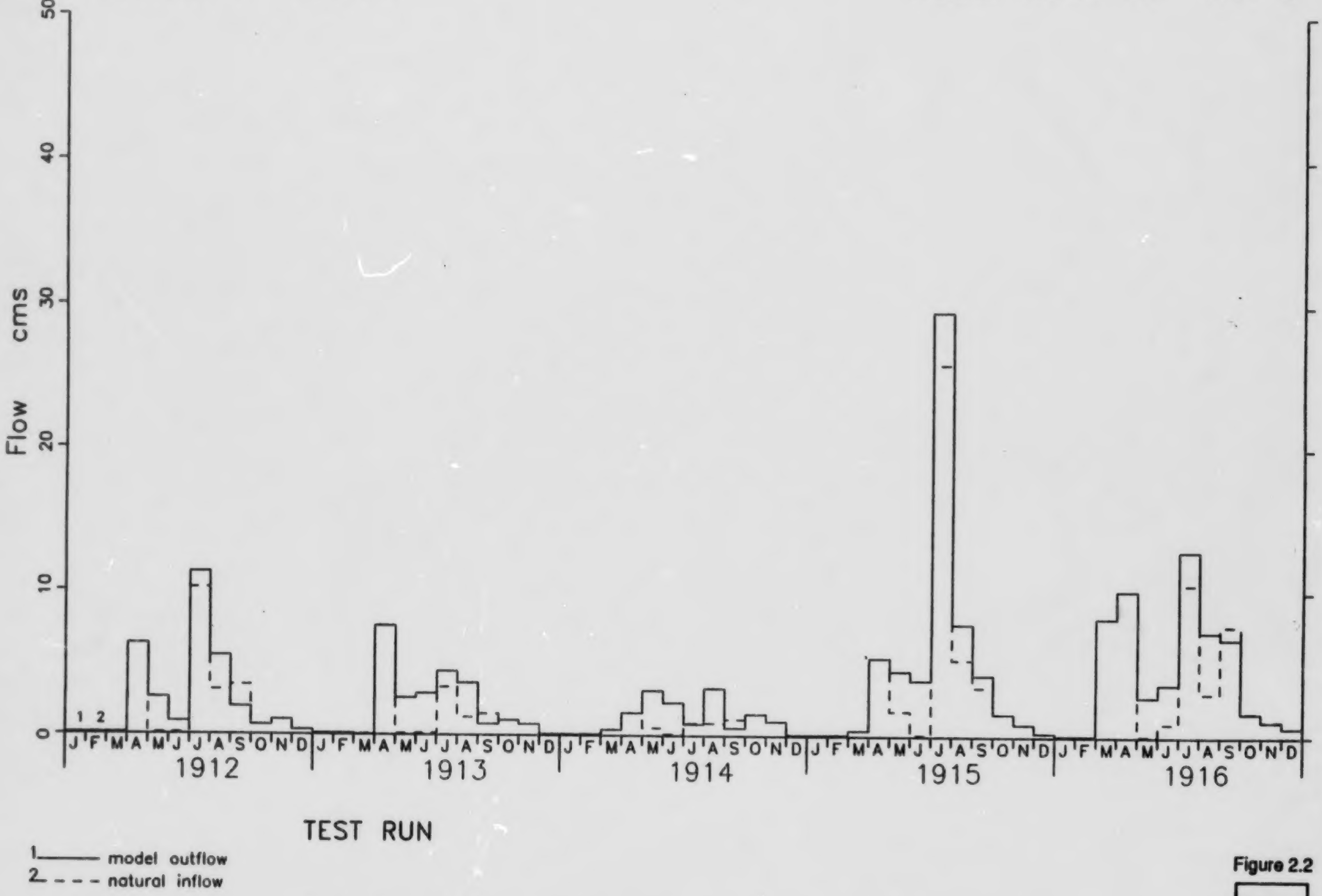


Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1999

Figure 2.3

MONTHLY FLOWS

Node: NODE 05 No. 5



TEST RUN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1999

Figure 2.2

ACRES

(b) Node Results: Irrigation Time Series

This plot is a time series of the total irrigation intake and consumption requirements at a node presented in a bar chart format. In this case, consumption is defined as the total amount of water not returned to the node being plotted. Therefore, if a node supplies an irrigation area which returns water to a downstream node, then all intake is considered to be consumed when plotting results at the supply node.

A sample of the graph is included in Figure 2.3.

The format of the OUTFLOWS.DAT file created by MODULE 8 of the simulation program was modified to support the generation of graphics. This has substantially increased the size of this output file.

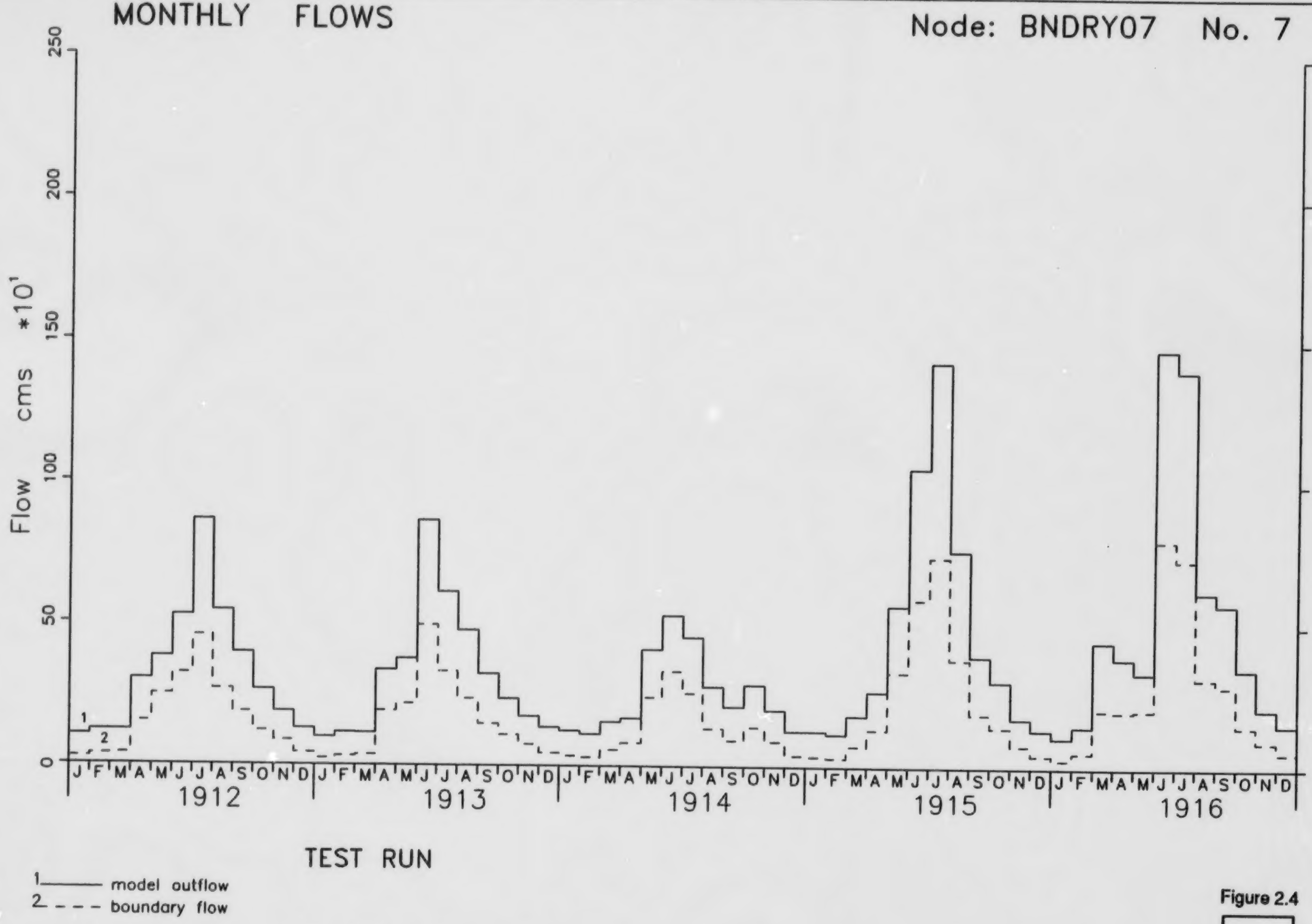
(c) Node Results: Boundary Flow Time Series

This plot is a bar chart of the time series of simulated outflows and the required boundary flow at a node. A sample is shown in Figure 2.4. This plot is useful in examining flow shortages at boundary nodes.

(d) Node Results: Energy Time Series

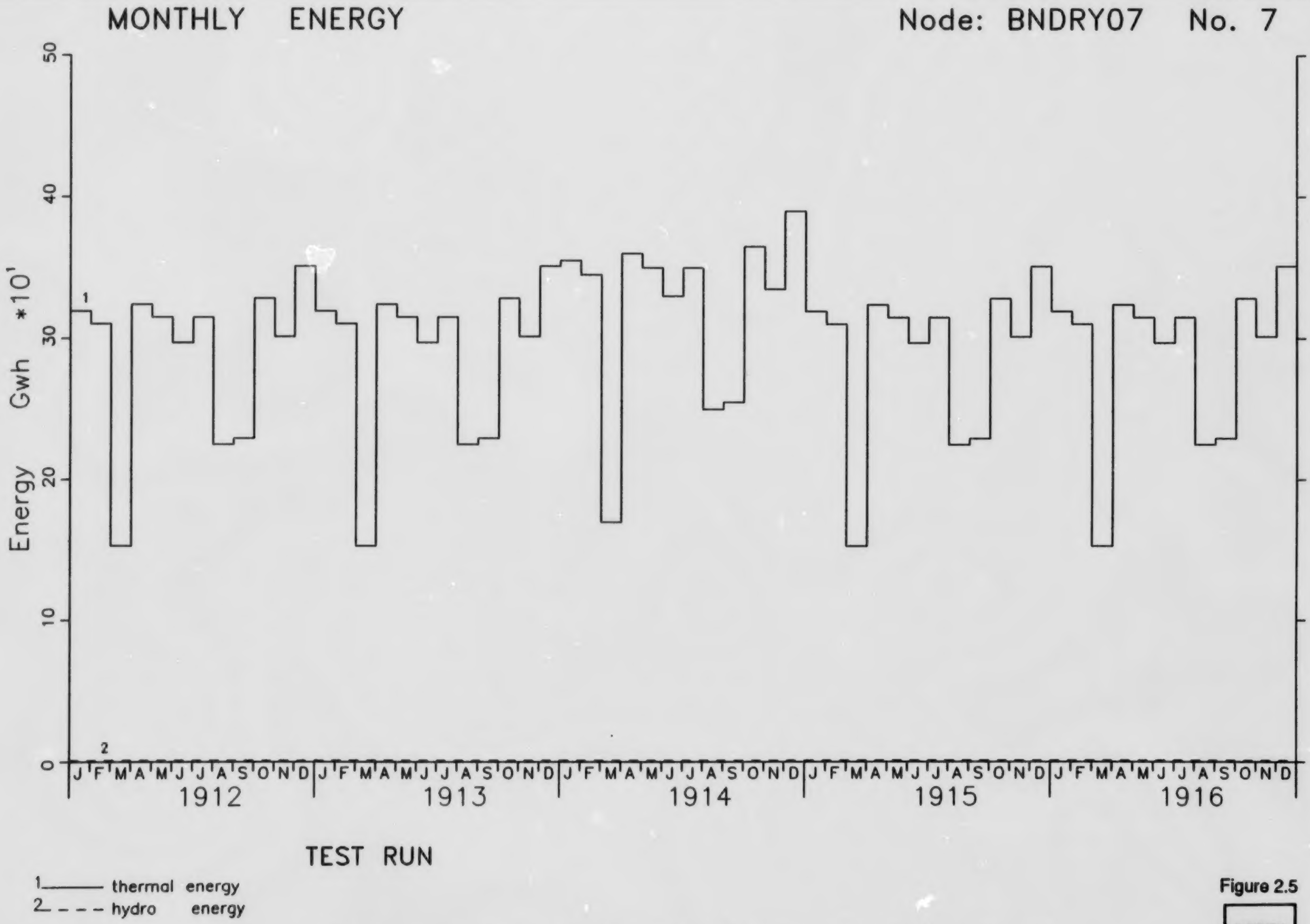
This plot is a time series bar chart of the total hydro and thermal energy generation of a node. A separate bar is included for each energy type as shown in Figure 2.5.

A new file called PLOTTER.HYD is now created by MODULE 10 of the program to save the hydro energy data required for plotting. Therefore, a user must run MODULE 10, after completing a simulation run using MODULE 8 before attempting to produce energy graphs using the MODULE 9 plot program.



Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1999

Figure 2.4



TEST RUN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1999

Figure 2.5

(e) Reservoir Results - Summaries

Summary bar charts were added to present statistical evaluations of the reservoir elevation and release. These plots indicate the percentage of occurrence, in each month, for specified ranges of elevation or discharge.

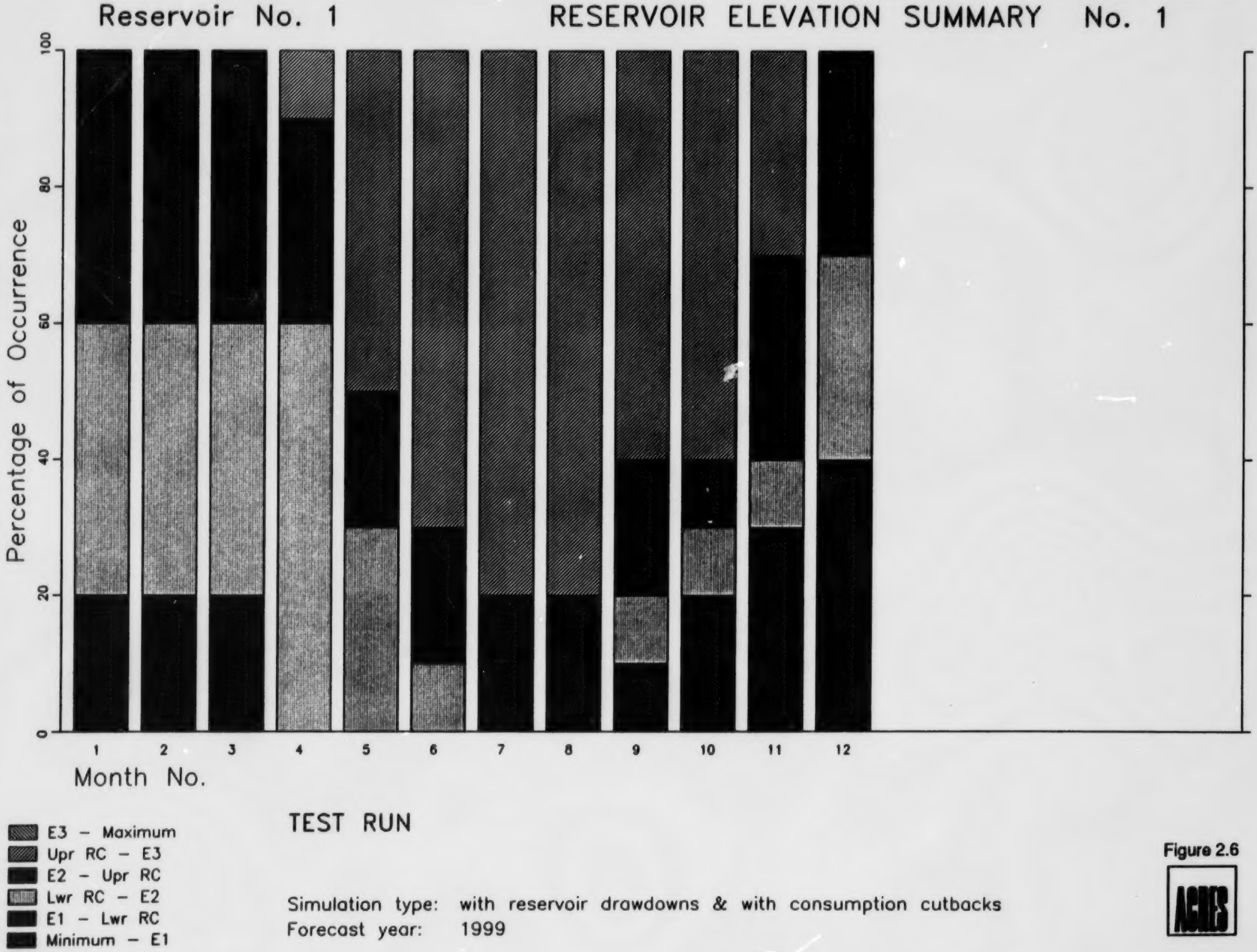
Figure 2.6 shows an example of a reservoir elevation frequency diagram. The ranges used are

- minimum level to evaluation level 1
- evaluation level 1 to lower rule curve
- lower rule curve to evaluation level 2
- evaluation level 2 to upper rule curve
- upper rule curve to evaluation level 3
- evaluation level 3 to maximum level.

Figure 2.7 shows an example of a reservoir release frequency diagram. The ranges used are

- zero to minimum release
- minimum release to evaluation flow 1
- evaluation flow 1 to target outflow
- target outflow to evaluation flow 2
- evaluation flow 2 to maximum release
- over maximum release.

The evaluation values are supplied by the user in the gauge data files with the other reservoir data including rule curve levels, target flow, minimum release, maximum no damage release, etc. If the user does not supply evaluation values they will be set by the program equal to the average of the two adjoining limits. The gauge data file format was revised to accommodate the graphics option. This necessitated changes to other affected program modules.



TEST RUN

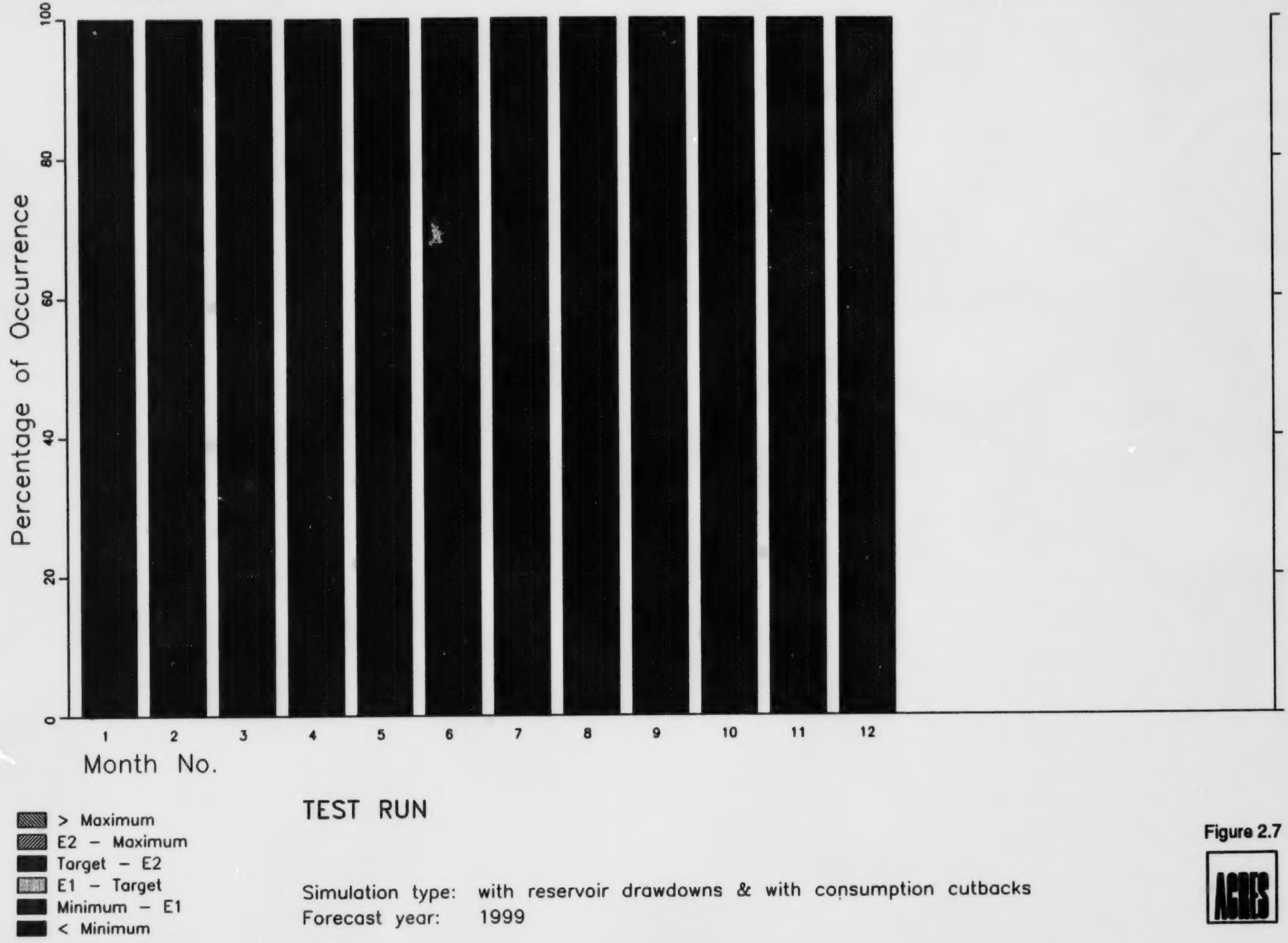
Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1999

Figure 2.6

ACRES

Reservoir No. 1

RESERVOIR OUTFLOW SUMMARY No. 1



TEST RUN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1999

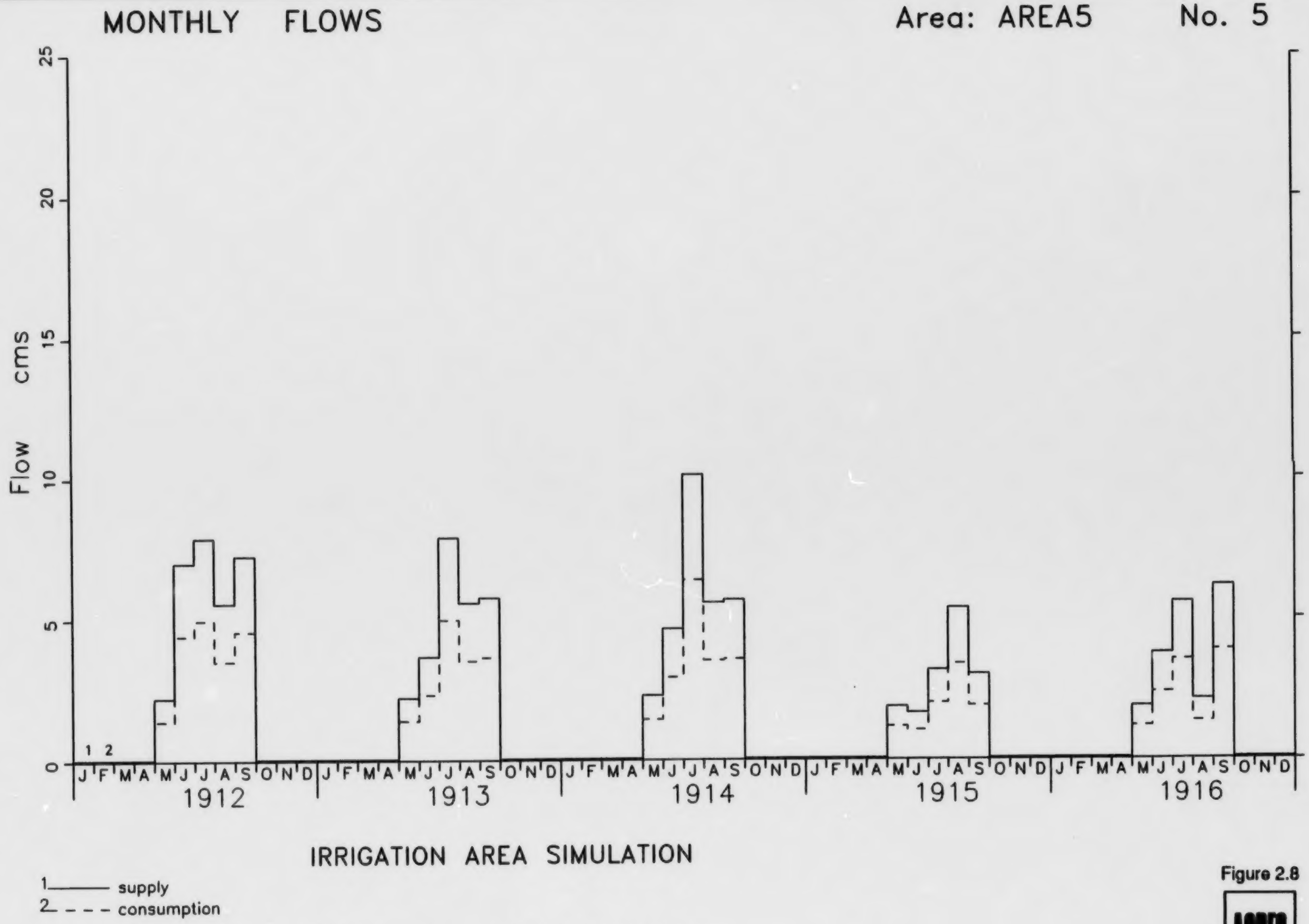
Figure 2.7

ACRES

(f) Irrigation Area Results: Demand Time Series

This plot shows the calculated time series of irrigation supply and consumption at a particular irrigation area. The graph uses data from the area run file calculated in MODULE 7b. The graph can be created before running the main network simulation program (MODULE 8).

Figure 2.8 shows an example of this plot.



Simulation type: irrigation analysis only
Forecast year: 1999

Figure 2.8

3 - APPLICATION TO SCENARIO EVALUATIONS

3 - APPLICATION TO SCENARIO EVALUATIONS

3.1 - Objectives and Scope

The objectives of the model applications in this phase are as follows

- to generally test and demonstrate the effects of the model and data base enhancements in the areas of industrial water use analysis, reservoir operations and graphics

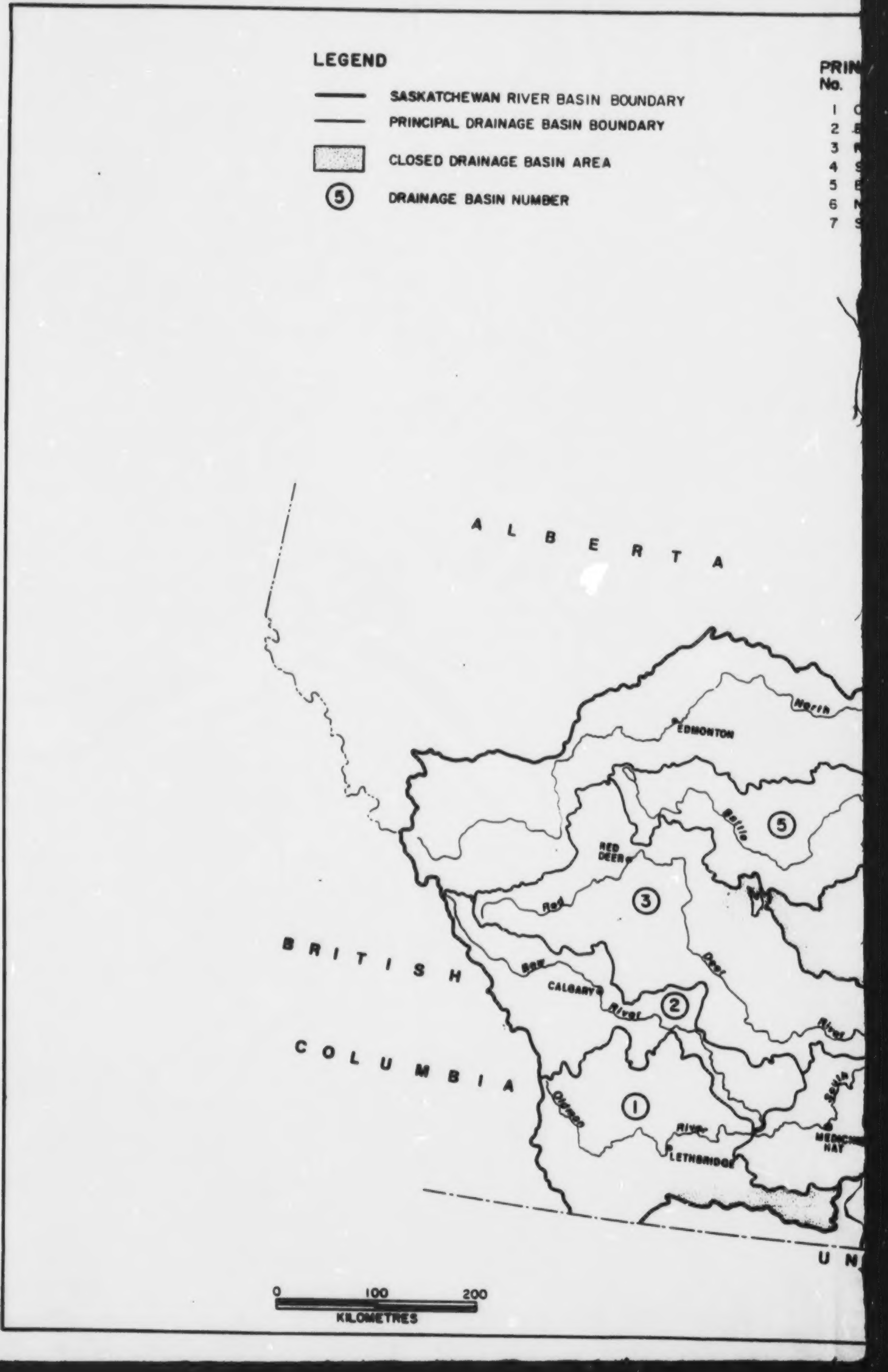
- to update and extend the Phase VI scenario data and evaluations for the full Saskatchewan River basin in Alberta and Saskatchewan, up to the year 2011.

The modified river basin is that of the Saskatchewan River from the confluence of the North and South Saskatchewan rivers to the Manitoba border, together with the various principal tributaries. In addition to the 1982 base case, likely development scenarios for the years 2001 and 2011 have been prepared and evaluated. Although the 1991 scenario has not been evaluated in this phase, the corresponding data sets have been updated where appropriate and have been maintained in the prepared data base.

3.2 - Modeling the Saskatchewan River Basin

The principal drainage basins within the Saskatchewan River basin are shown in Figure 3.1. As in previous phases, these have been subdivided into subbasins as shown in Figure 3.2. Each subbasin is defined by a streamflow gauging station at its downstream point.

For modeling purposes, the basin is represented by the flow network shown in Figure 3.3. This is essentially a set of streamflow arcs linking gauging station nodes and including the interrelationships with


LEGEND
SASKATCHEWAN RIVER BASIN BOUNDARY
PRINCIPAL DRAINAGE BASIN BOUNDARY
CLOSED DRAINAGE BASIN AREA
⑤ DRAINAGE BASIN NUMBER
PRIN
No.
1 C
2
3
4 S
5 E
6 N
7 S
ALBERTA
BRITISH COLUMBIA
North
EDMONTON
Battle
⑤
RED DEER
Red
③
Deer
River
Bow
CALGARY
River
②
①
Oldman
River
LETHBRIDGE
South
MEDICIN
HAT
U N
0
100
200
KILOMETRES

PRINCIPAL DRAINAGE BASINS

No.	NAME
1	OLDMAN
2	BOW
3	RED DEER
4	SOUTH SASKATCHEWAN
5	BATTLE
6	NORTH SASKATCHEWAN
7	SASKATCHEWAN

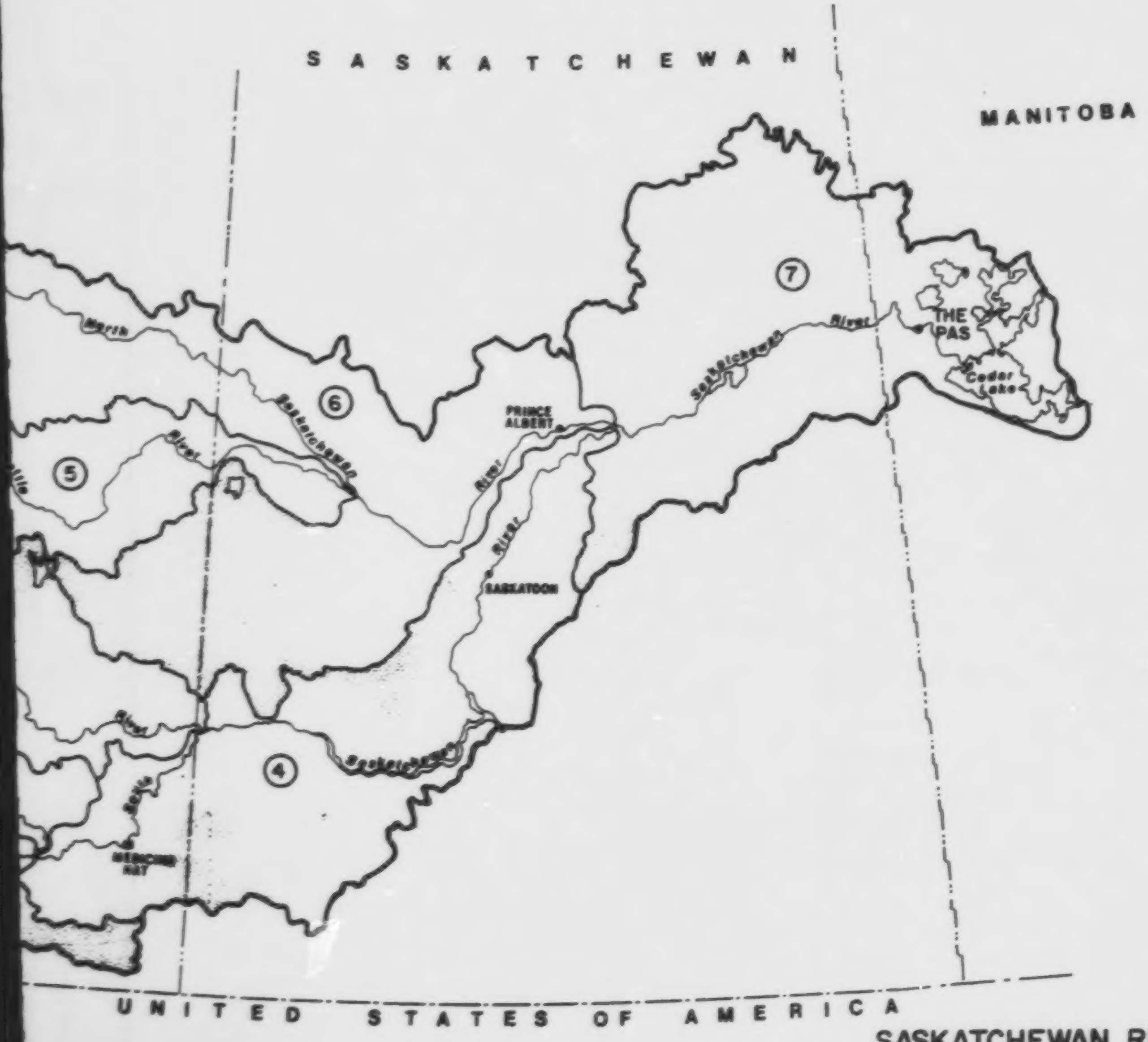

SASKATCHEWAN
MANITOBA
⑦
THE PAS
Cedar Lake
Saskatchewan River
North
Saskatchewan
⑥
PRINCE ALBERT
River
⑤
Battle
River
SASKATOON
River
Saskatchewan
④
Bow
MEDICINE HAT
UNITED STATES OF AMERICA

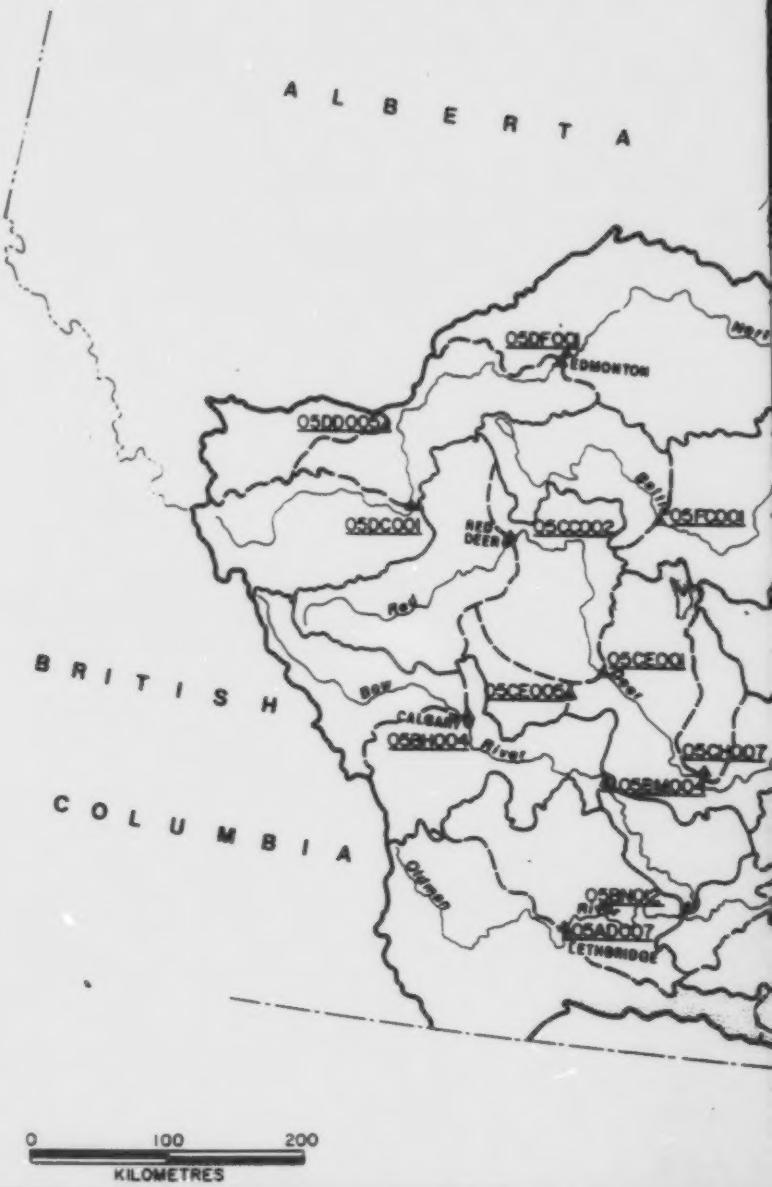
FIG. 3.1

SASKATCHEWAN RIVER BASIN
PRINCIPAL DRAINAGE BASINS

LEGEND

▬	SASKATCHEWAN RIVER BASIN BOUNDARY
—	PRINCIPAL DRAINAGE BASIN BOUNDARY
▨	CLOSED DRAINAGE BASIN AREA
— — —	SUBBASIN BOUNDARY
▲ 05AD007	STREAMFLOW GAUGING STATION

I.D. No.
05AD007
05AJ001
05AK001
05BH004
05BM004
05BN012
05CC002
05CE001
05CE005
05CH007
05CK004
05DC001
05DD005
05DF001
05EF001


ALBERTA
BRITISH COLUMBIA
05DF001
EDMONTON
05DD005
05DC001
RED DEER
05CC002
05FC001
Battle
Red
Deer
05CE001
05CE005
Bow
CALGARY
05BH004
River
05CH007
05BM004
Oldman
05BN012
River
05AD007
LETHBRIDGE
0
100
200
KILOMETRES

GAUGING STATIONS

I.D. No.	LOCATION
05AD007	OLDMAN RIVER NEAR LETHBRIDGE
05AJ001	SOUTH SASK. RIVER AT MEDICINE HAT
05AK001	SOUTH SASK. RIVER AT HIGHWAY No. 41
05BH004	BOW RIVER AT CALGARY
05BM004	BOW RIVER BELOW BASSANO DAM
05BN012	BOW RIVER NEAR THE MOUTH
05CC002	RED DEER RIVER AT RED DEER
05CE001	RED DEER RIVER AT DRUMHELLER
05CE005	ROSEBUD RIVER AT REDLAND
05CH007	BERRY CREEK NEAR THE MOUTH
05CK004	RED DEER RIVER NEAR BINDLOSS
05DC001	NORTH SASK. R. NEAR ROCKY MOUNTAIN HOU:
05DD005	BRAZEAU RIVER BELOW BRAZEAU PLANT
05DF001	NORTH SASK. RIVER AT EDMONTON
05EF001	NORTH SASK. RIVER NEAR DEER CREEK

I. D. No.	LOCATION
05FC001	BATTLE RIVER NEAR FORESTBURG
05FE001	BATTLE RIVER NEAR UNWIN
05FF001	BATTLE RIVER AT BATTLEFORD
05GC006	EAGLE CREEK NEAR ENVIRON
05GG001	NORTH SASK. RIVER AT PRINCE ALBERT
05HD039	SWIFT CURRENT CREEK NEAR LEINAN
05HG001	SOUTH SASK. RIVER AT SASKATOON
05HH001	SOUTH SASK. RIVER AT ST. LOUIS
05KJ001	SASKATCHEWAN RIVER AT THE PAS

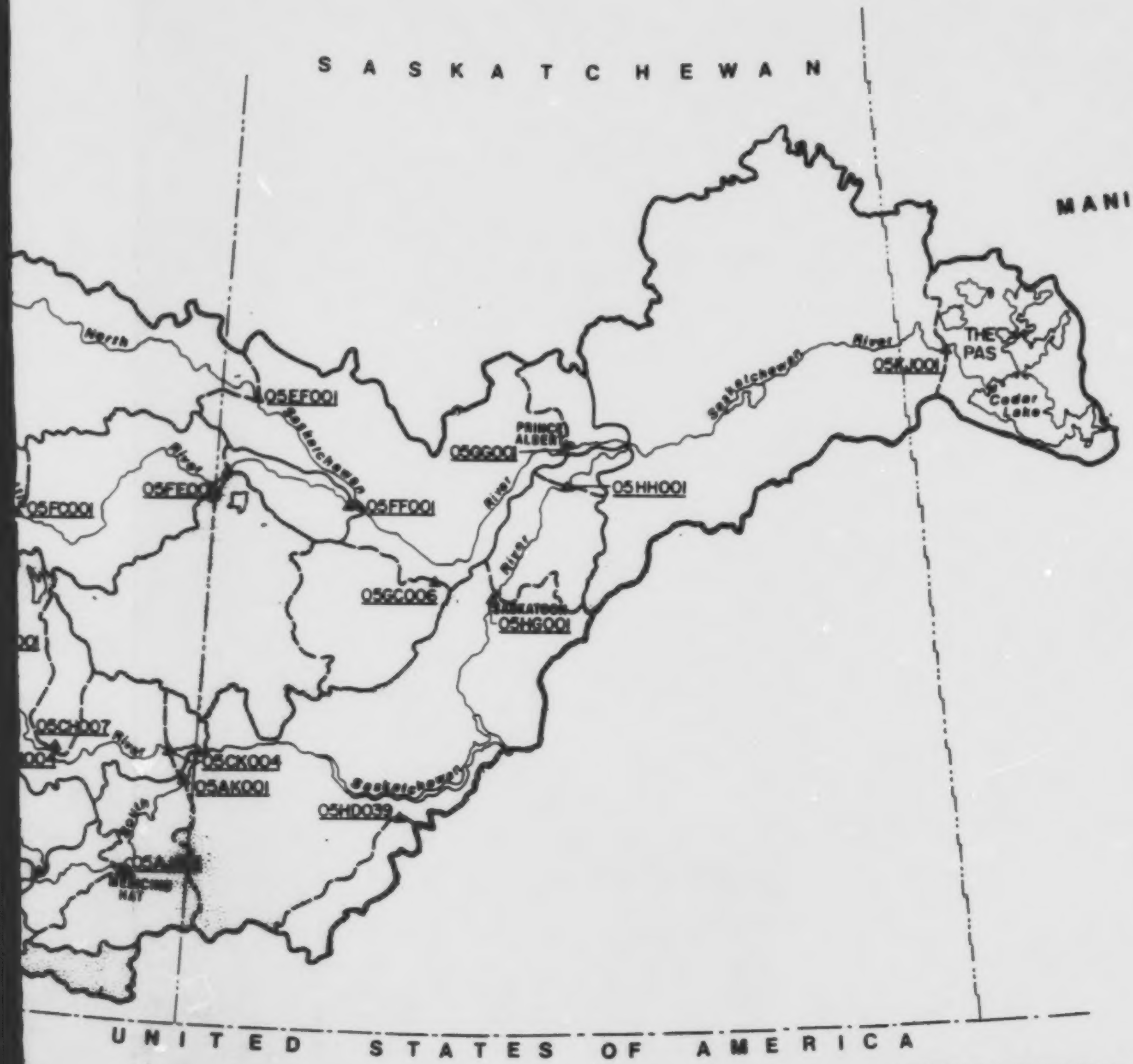
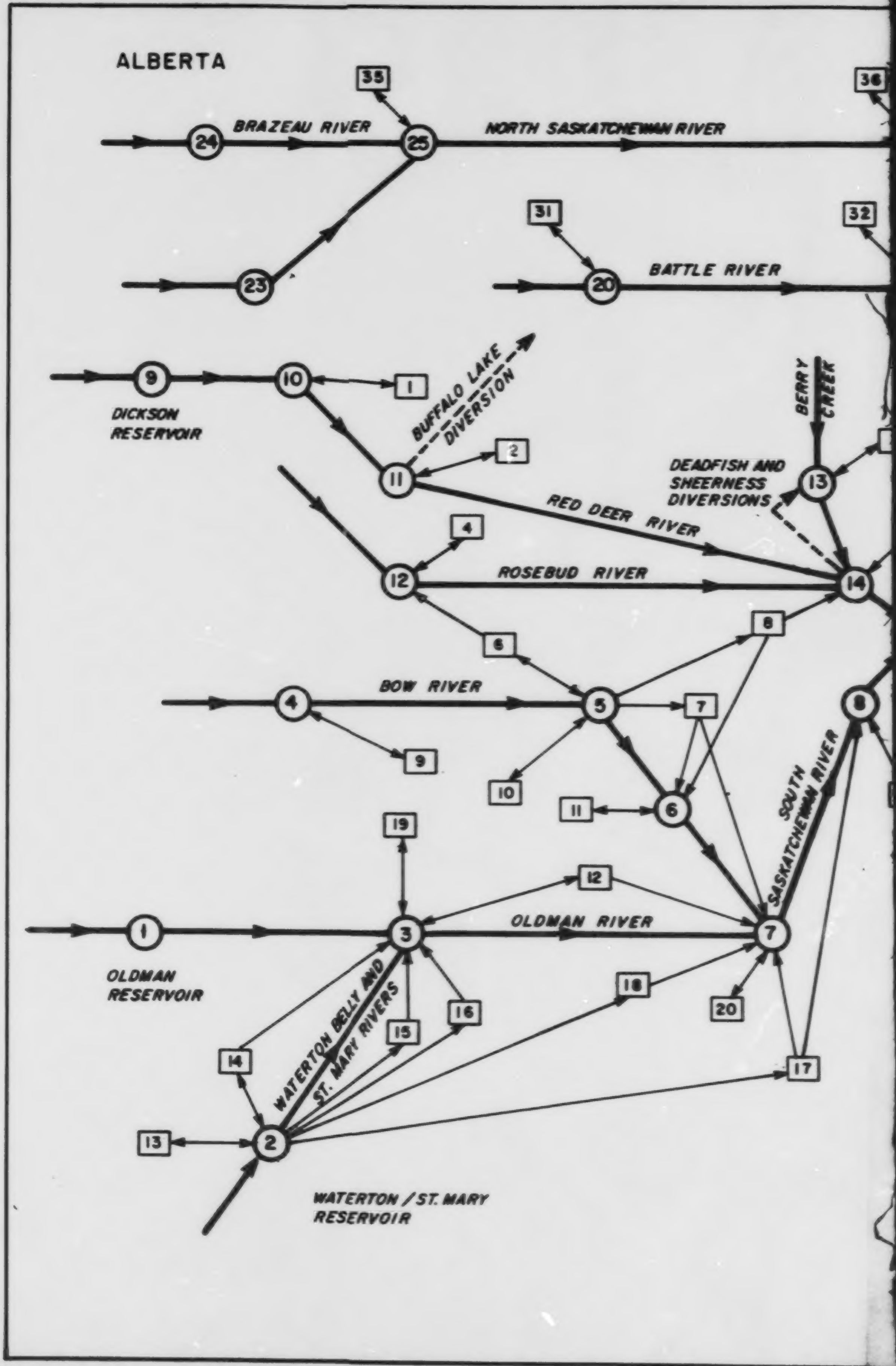

SASKATCHEWAN
MANITOBA
North
05EF001
Saskatchewan
River
05FE001
05FC001
05FF001
PRINCE ALBERT
05GG001
River
05HH001
Saskatchewan
River
05KJ001
THE PAS
Cedar Lake
05GC006
River
SASKATOON
05HG001
001
05CH007
River
004
05CK004
05AK001
South
Saskatchewan
05HD039
MEDICINE HAT
UNITED STATES OF AMERICA

FIG.3.2

SASKATCHEWAN RIVER BASIN
SUBBASINS AND GAUGING STATIONS


ALBERTA
BRAZEAU RIVER
NORTH SASKATCHEWAN RIVER
BATTLE RIVER
DICKSON RESERVOIR
BUFFALO LAKE DIVERSION
BERRY CREEK
DEADFISH AND SHEERNESS DIVERSIONS
RED DEER RIVER
ROSEBUD RIVER
BOW RIVER
SOUTH SASKATCHEWAN RIVER
OLDMAN RIVER
OLDMAN RESERVOIR
WATERTON BELLY AND ST. MARY RIVERS
WATERTON / ST. MARY RESERVOIR

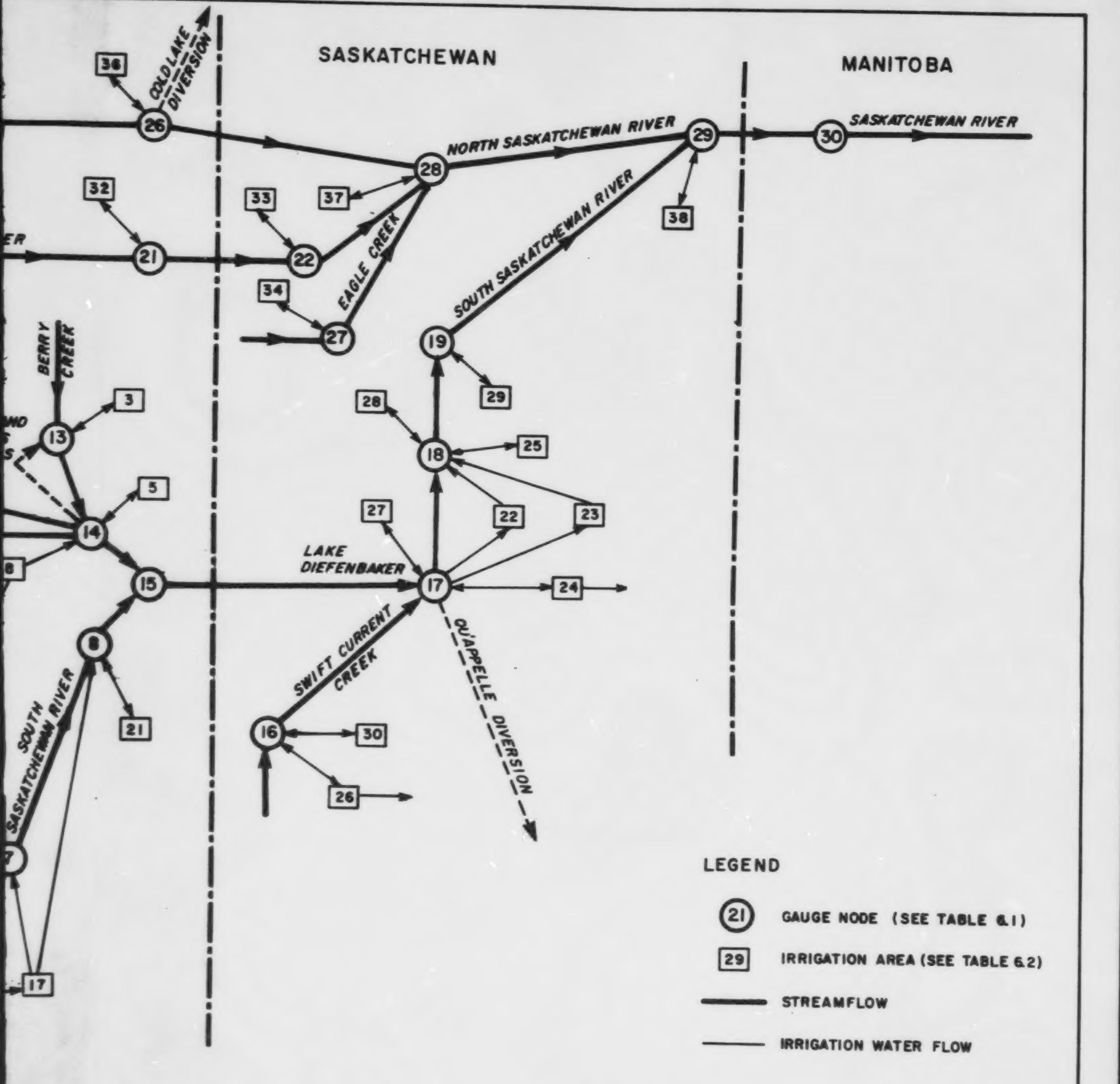

SASKATCHEWAN
MANITOBA
COLD LAKE DIVERSION
36
26
NORTH SASKATCHEWAN RIVER
29
30
SASKATCHEWAN RIVER
28
32
33
37
38
21
22
EAGLE CREEK
SOUTH SASKATCHEWAN RIVER
34
27
19
29
BERRY CREEK
3
13
28
18
25
5
14
27
22
23
LAKE DIEFENBAKER
15
17
24
8
SWIFT CURRENT CREEK
QU'APPELLE DIVERSION
21
16
30
26
SOUTH SASKATCHEWAN RIVER
17
LEGEND
21 GAUGE NODE (SEE TABLE 6.1)
29 IRRIGATION AREA (SEE TABLE 6.2)
STREAMFLOW
IRRIGATION WATER FLOW

FIG. 3.3

SASKATCHEWAN RIVER BASIN
FLOW NETWORK

irrigation areas and flows. Tables 3.1 and 3.2 identify the streamflow gauge nodes and the irrigation areas, respectively. The gauge nodes are located at subbasin outlets and are identified by the Water Survey of Canada (WSC) gauge number. Each of these subbasins are composed of a number of constituent WSC subbasins which are also listed in Table 3.1.

The network includes six additional nodes which are used to model specific items. Four of these represent reservoirs (Oldman, Waterton/ St. Mary, Dickson and Diefenbaker reservoirs), and the remaining two are dummy nodes used to monitor simulated apportionment flows at the two provincial boundaries. Also shown on the network are the locations of the modeled diversions. The effects of reservoirs and diversions are evaluated only as they are specified and brought on-line for each scenario.

3.3 - Definition of Evaluated Scenarios

The scenarios considered in this phase are defined as follows.

(a) Base Case, 1982 - This case represents the level of development in 1982, which is the base year for all WUAM evaluations. With the exception of irrigation area data, basic data actually corresponds to 1981, this being the year for which data was available at the time of initial preparation of the data base. Model forecasts are applied to advance the 1981 data to 1982 when the base case is analyzed.

(b) Committed Scenario, 1991 - This scenario represents the level of development expected for 1991, based on completion of ongoing or committed projects. Earliest likely implementation dates are assumed. This is a conservative approach, in that water demand will tend to be overestimated rather than underestimated. The 1991 scenario has not been evaluated in this phase, but it has

TABLE 3.1

SASKATCHEWAN RIVER BASIN - STREAMFLOW GAUGES

Node No.	Gauge No.	Location	Local Constituent Subbasins
1	OLD_RES	Oldman Reservoir	-
2	WSM_RES	Waterton/St. Mary Reservoir	-
3	05AD007	Oldman River near Lethbridge	05AA, 05AB, 05AD, 05AE, 05AF
4	05BH004	Bow River at Calgary	05BA, 05BB, 05BC, 05BD, 05BE, 05BF, 05BG, 05BH
5	05BM004	Bow River below Bassano Dam	05BJ, 05BK, 05BL, 05BM
6	05BN012	Bow River near mouth	05BN
7	05AJ001	South Saskatchewan River at Medicine Hat	05AC, 05AJ, 05AG
8	05AK001	South Saskatchewan River at Highway 41	05AK, 05AH
9	DICKRES	Dickson Reservoir	-
10	05CC002	Red Deer at Red Deer	05CA, 05CB, 05CC
11	05CE001	Red Deer at Drumheller	05CD
12	05CE005	Rosebud River at Redland	05CE
13	05CH007	Berry Creek near mouth	05CH
14	05CK004	Red Dear River near Bindloss	05CJ, 05CK, 05CG
15	DUMMY01	Dummy Node - just inside Alberta	-
16	05HD039	Swift Current Creek near Leinan	05HD
17	DIEFRES	Lake Diefenbaker	-
18	05HG001	South Saskatchewan River at Saskatoon	05HB, 05HC, 05HE, 05HF, 05HG
19	05HH001	South Saskatchewan River at St. Louis	05HH
20	05FC001	Battle River near Forestburg	05FA
21	05FE001	Battle River near Unwin	05FB, 05FC, 05FD, 05FE
22	05FF001	Battle River at Battleford	05FF
23	05DC001	North Saskatchewan River near Rocky Mountain House	05DA, 05DC, 05DB
24	05DD005	Brazeau River below Brazeau Plant	05DD
25	05DF001	North Saskatchewan River at Edmonton	05DE, 05DF
26	05EF001	North Saskatchewan River near Deer Creek	05EA, 05EB, 05EC, 05ED, 05EE
27	05GC006	Eagle Creek near Environ	05GC
28	05GG001	North Saskatchewan River at Prince Albert	05EF, 05EG, 05GD, 05GE, 05GF
29	05KJ001	Saskatchewan River at The Pas	05KA, 05KB, 05KC, 05KD, 05KE, 05KF, 05KG, 05KH, 05KJ, 05GG
30	DUMMY02	Dummy Node - just inside Manitoba	-

TABLE 3.2

SASKATCHEWAN RIVER BASIN - IRRIGATION AREAS

Area No.	Area No.	Area Name*
1	RDR-PIA	Red Deer River PI-Area A
2	RDR-PIB	Red Deer River PI-Area B
3	RDR-PIC	Red Deer River PI-Area C (1)
4	RDR-PID	Red Deer River PI-Area D
5	RDR-PIE	Red Deer River PI-Area E (2)
6	WEST-ID	Western ID
7	BOW-ID	Bow River ID
8	EAST-ID	Eastern ID
9	BOW-PIA	Bow River PI-Area A
10	BOW-PIB	Bow River PI-Area B (3)
11	BOW-PIC	Bow River PI-Area C
12	LETH-ID	Lethbridge Northern ID
13	MVLA-ID	Mountain View, Leavitt and Aetna ID
14	UNIT-ID	United ID
15	MAGR-ID	Magrath ID
16	RAYM-ID	Raymond ID
17	STMR-ID	St. Mary River ID (4)
18	TABR-ID	Taber ID
19	OLD-PIA	Oldman River PI-Area A (5)
20	OLD-PIB	Oldman River PI-Area B (6)
21	SSRA-PI	South Saskatchewan River (Alberta) PI (7)
22	SSR-ID	South Saskatchewan River ID (8)
23	SSEWSS	Saskatoon Southeast Water Supply System (9)
24	SSRWUDA	South Saskatchewan River WUD-Area A (10)
25	SSRWUDB	South Saskatchewan River WUD-Area B (11)
26	SCCWUD	Swift Current Creek WUDs (12)
27	SSR-PIA	South Saskatchewan River (Sask) PI-Area A
28	SSR-PIB	South Saskatchewan River (Sask) PI-Area B
29	SSR-PIC	South Saskatchewan River (Sask) PI-Area C
30	SCC-PI	Swift Current Creek PI
31	BAT-PIA	Battle River PI-Area A
32	BAT-PIB	Battle River PI-Area B
33	BAT-PIC	Battle River PI-Area C
34	EAG-PI	Eagle Creek PI
-	-	North Saskatchewan River PI-Area A
-	-	North Saskatchewan River PI-Area B
35	NSR-PIC	North Saskatchewan River PI-Area C
36	NSR-PID	North Saskatchewan River PI-Area D
37	NSR-PIE	North Saskatchewan River PI-Area E
38	SR-PI	Saskatchewan River PI

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*ID - Irrigation District(s); WUD - Water Users District(s); PI - Private Irrigation.

Table 3.2
Saskatchewan River Basin - Irrigation Areas - 2

Notes:

(1) includes Deadfish and Sheerness irrigation areas.
(2) includes Special Areas irrigation areas.
(3) includes Blackfoot and Little Bow expansion irrigation areas.
(4) includes western, central and eastern components.
(5) includes Blood and Peigan irrigation areas.
(6) includes Little Bow private irrigation area.
(7) includes Ross Creek ID.
(8) includes No. 1 (Outlook/East Side) and No. 2 (Conquest/West Side).
(9) includes irrigation areas (e.g., Blackstrap) which are supplied from the SSEWSS.
(10) includes Chesterfield Flats, Miry Creek, Riverhurst, Thunder Creek-Mortlach, Grainland, Bridgeford-Tugaske, Luck Lake and Macrorie irrigation areas.
(11) includes French Flats and Moon Lake irrigation areas.
(12) includes North Waldeck, Rush Lake and Herbert irrigation areas.

been reviewed and modified as appropriate and has served as a basis for developing the subsequent scenarios.

(c) Future Scenarios, 2001 and 2011 - These scenarios represent likely levels of development envisaged for 2001 and 2011, based on available information and 'main line' projections to the extent that these can be identified or estimated. As with the 1991 committed scenario, earliest likely implementation schedules are assumed.

3.4 - Scenario Assumptions

Assumptions pertaining to the four scenarios defined above are presented in the following subsections grouped according to the following major topics

- water resources (streamflow, reservoirs, diversions, groundwater)
- urban, rural, livestock and industrial water use
- irrigation water use
- energy project water use
- minimum flow requirements.

3.4.1 - Water Resources

- PPWB natural monthly streamflows, or derivations from these, are used throughout, the period of simulation being 1912 to 1967.

- PPWB K-file adjustments are used to account for storage and evaporation effects upstream of the Waterton/St. Mary reservoir, in the upper Bow River reservoirs and in the Reid Lake reservoir.

- Similar derived adjustments are used to account for storage and evaporation effects of the Bighorn and Brazeau reservoirs.

- The Waterton/St. Mary reservoir system and Lake Diefenbaker reservoir are explicitly modeled and on stream for all scenarios (see Table 3.3).

- The Oldman and Dickson reservoirs are explicitly modeled and on stream for the 1991, 2001 and 2011 scenarios (see Table 3.3).

- The Qu'Appelle diversion from Lake Diefenbaker to the external Qu'Appelle River basin is included, with an increasing annual volume through all the scenarios (see Table 3.4). The diversion is appropriately distributed through the year. The increase represents an estimated regional growth of 28% every 10 years. An additional diversion allowance of 15% is included for the 2011 irrigation season. This reflects a potential shift in irrigation development emphasis after 2001 from the South Saskatchewan basin to the Qu'Appelle basin.

- The Buffalo Lake diversion from above Drumheller to Buffalo Lake is included, with no return flow to the main stem system, at the same annual volume for the 1991 and subsequent scenarios (see Table 3.4) The diversion is taken uniformly over 7 months of the year.

- The Deadfish and Sheerness diversions from above Bindloss into Berry Creek are included (see Table 3.4). The Deadfish diversion is set at a constant annual volume for the 1991 and subsequent scenarios, and is taken uniformly over 4 months of the year. The Sheerness diversion volume excludes the corresponding thermal power plant water intake volume, which is modeled separately. For the 1991 and subsequent scenarios, it is set at a constant annual volume which reflects current development perspectives. Diversion water is taken uniformly over 8 months of the year but is released over 5 months of the year, to help meet irrigation demands.

TABLE 3.3

RESERVOIR SCENARIO DATA

Name	Node No.	Node ID	Scenario Years On Stream	Full Supply Storage (Mm³)	Minimum Operating Storage (Mm³)	Maximum 'No Damage' Release (m³/s)	Minimum Riparian Release (m³/s)
Oldman	1	OLD_RES	1991 2001 2011	503	6.6	500	10.0
Waterton/St. Mary	2	WSM-RES	1982 1991 2001 2011	573	73.0	885	2.6*
Dickson	9	DICKRES	1991 2001 2011	210	16.0	500	16.0
Lake Diefenbaker	17	DIEFRES	1982 1991 2001 2011	9373	5424.0	600	42.5

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*Average over the year.

TABLE 3.4

DIVERSION SCENARIO DATA

Name	Annual Volume (Mm^3)	Donating Node		Receiving Node	
		No.	ID	No.	ID
1982 Base Case					
Qu'Appelle	58.9	17	DIEFRES	-	-
1991 Committed Scenario					
Buffalo Lake	37.0	11	05CE001	-	-
Sheerness*	30.0	14	05CK004	13	05CH007
Deadfish	15.0	14	05CK004	13	05CH007
Qu'Appelle	75.4	17	DIEFRES	-	-
2001 Future Scenario					
Buffalo Lake	37.0	11	05CE001	-	-
Sheerness*	30.0	14	05CK004	13	05CH007
Deadfish	15.0	14	05CK004	13	05CH007
Qu'Appelle	96.6	17	DIEFRES	-	-
2011 Future Scenario					
Buffalo Lake	37.0	11	DIEFRES	-	-
Sheerness*	30.0	14	DIEFRES	-	-
Deadfish	15.0	14	DIEFRES	-	-
Qu'Appelle	134.0	17	DIEFRES	-	-
Cold Lake	71.3	26	05EF001	-	-

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*Nonthermal power component.

- The Cold Lake diversion from the North Saskatchewan River into the Beaver River basin is included in the 2011 scenario to allow for potential significant development of oil sands projects.

- As in Phase VI, groundwater supply for urban (municipal) and industrial water use in each subbasin is based on IW/L data, while groundwater supply for other water use sectors is based on provincial default values.

3.4.2 - Urban, Rural, Livestock and Industrial Water Use

- Urban and rural population growth rates correspond to the Statistics Canada forecast, Scenario No. 1, 'fertility increase and some migration'. Updated forecasts were obtained in this phase (Reference 17) and were processed and incorporated into the data base.

- Livestock population growth rates correspond to the forecast previously derived for the model, Scenario No. 2, 'expected growth', as in Phase VI.

- Industrial sector growth rates correspond to the Informetrica forecast 1981 - 2005, incorporated into the data base in this phase.

3.4.3 - Irrigation Water Use

- Irrigation area supply and return flow percentages are allocated as derived in previous phases, with modifications as required by the explicit modeling of the Waterton/St. Mary reservoir system in this phase (see Table 3.5). All allocations are assumed constant with time, except for return flow allocations for Water Users Districts supplied from Lake

Diefenbaker. These change according to the assumed expansion of development into the Qu'Appelle River basin, as follows.

Scenario Year	Return Flow Allocation (%) Lake Diefenbaker	Qu'Appelle River Basin
1982	100	0
1991	80	20
2001	60	40

- Rainfall and irrigation type application efficiencies remain as estimated in previous phases (see Table 3.6). Application efficiency is effective application as a percentage of actual applications.

- Crop, soil and irrigation type areal distributions remain as estimated in previous phases (see Table 3.7).

- As before, crop irrigation levels are generally set to reflect small increases through all the scenarios, up to a uniform but low value (see Tables 3.8, 3.9 and 3.10). Crop irrigation level is actual irrigation as a percentage of optimal irrigation. Optimal irrigation is the irrigation required to achieve maximum crop yield.

- Also as before, delivery efficiencies and evaporative losses are set to reflect the recent and ongoing rehabilitation programs in Alberta, and the perceived intent to improve current system operations before major new developments are undertaken (see Tables 3.8, 3.9, 3.10 and 3.11). Uniformly high efficiencies are shown as achieved by 2001, generally in conjunction with low evaporation losses. However, evaporative losses will remain comparatively high for those systems which incorporate off-stream storage reservoirs. Note that delivery

TABLE 3.5

IRRIGATION SCENARIO DATA -
IRRIGATION AREAS AND CORRESPONDING SUBBASINS

Irrigation Area			Corresponding Subbasin Nodes					
No.	Name*	ID	Supply Node		Return Nodes			
			(No.)	(ID)	(No.)	(%)	(No.)	(%)
1	Red Deer PI-Area A	RDR-PIA	10	05CC002	10	100		
2	Red Deer PI-Area B	RDR-PIB	11	05CE001	11	100		
3	Red Deer PI-Area C	RDR-PIC	13	05CH007	13	100		
4	Red Deer PI-Area D	RDR-PID	12	05CE005	12	100		
5	Red Deer PI-Area E	RDR-PIE	14	05CK004	14	100		
6	Western ID	WEST-ID	5	05BM004	5	55	12	45
7	Bow River ID	BOW-ID	5	05BM004	6	75	7	25
8	Eastern ID	EAST-ID	5	05BM004	6	30	14	70
9	Bow River PI-Area A	BOW-PIA	4	05BH004	4	100		
10	Bow River PI-Area B	BOW-PIB	5	05BM004	5	100		
11	Bow River PI-Area C	BOW-PIC	6	05BN012	6	100		
12	Lethbridge Northern ID	LETH-ID	3	05AD007	3	30	7	70
13	Mountain View, Leavitt and Aetna ID	MVLA-ID	2	WSM_RES	2	100		
14	United ID	UNIT-ID	2	WSM_RES	2	25	3	75
15	Magrath ID	MAGR-ID	2	WSM_RES	3	100		
16	Raymond ID	RAYM-ID	2	WSM_RES	3	100		
17	St. Mary River ID	STMR-ID	2	WSM_RES	7	70	8	30
18	Taber ID	TABR-ID	2	WSM_RES	7	100		
19	Oldman River PI-Area A	OLD-PIA	3	05AD007	3	100		
20	Oldman River PI-Area B	OLD-PIB	7	05AJ001	7	100		
21	South Saskatchewan River (Alb) PI	SSRA-PI	8	05AK001	8	100		
22	South Saskatchewan River ID	SSR-ID	17	DIEFRES	18	100		
23	Saskatoon SEWS System	SSEWSS	17	DIEFRES	18	100		
24	South Saskatchewan River WUD-Area A	SSRWUDA	17	DIEFRES	17	100	0	0**
25	South Saskatchewan River WUD-Area B	SSRWUDB	18	05HG001	18	100		
26	Swift Current Creek WUD	SCCWUD	16	05HD039	16	20	0	80
27	South Sask. River (Sask) PI-Area A	SSR-PIA	17	DIEFRES	17	100		
28	South Sask. River (Sask) PI-Area B	SSR-PIB	18	05HG001	18	100		
29	South Sask. River (Sask) PI-Area C	SSR-PIC	19	05HB001	19	100		
30	Swift Current Creek PI	SCC-PI	16	05HD039	16	100		
31	Battle River PI-Area A	BAT-PIA	20	05FC001	20	100		
32	Battle River PI-Area B	BAT-PIB	21	05FE001	21	100		
33	Battle River PI-Area C	BAT-PIC	22	05FF001	22	100		
34	Eagle Creek PI	EAG-PI	27	05GC006	27	100		
-	North Saskatchewan River PI-Area A	-	-	-	-	-		
-	North Saskatchewan River PI-Area B	-	-	-	-	-		
35	North Saskatchewan River PI-Area C	NSR-PIC	25	05DF001	25	100		
36	North Saskatchewan River PI-Area D	N[illegible]R-PID	26	05EF001	26	100		
37	North Saskatchewan River PI-Area E	[illegible]-PIE	28	05GG001	28	100		
38	Saskatchewan River PI	SR-PI	29	05KJ001	29	100		

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* ID - Irrigation District(s); WUD - Water Users District(s); PI - Private Irrigation.

**Will vary with level of development.

TABLE 3.6

IRRIGATION SCENARIO DATA -
RAINFALL AND IRRIGATION TYPE APPLICATION EFFICIENCIES

Irrigation Area		Rainfall	Irrigation Type Application Efficiency (%)			
No.	Name*	Application Efficiency (%)	Furrow	Border Dike	Wheel Roll	Center Pivot
1	Red Deer PI-Area A	75	55	60	70	80
2	Red Deer PI-Area B	80	55	60	70	80
3	Red Deer PI-Area C	95	55	60	70	80
4	Red Deer PI-Area D	80	55	60	70	80
5	Red Deer PI-Area E	95	55	60	70	80
6	Western ID	80	55	60	70	80
7	Bow River ID	95	55	60	70	80
8	Eastern ID	95	55	60	70	80
9	Bow River PI-Area A	75	55	60	70	80
10	Bow River PI-Area B	80	55	60	70	80
11	Bow River PI-Area C	95	55	60	70	80
12	Lethbridge Northern ID	95	55	60	70	80
13	Mountain View, Leavitt and Aetna ID	80	55	60	70	80
14	United ID	80	55	60	70	80
15	Magrath ID	95	55	60	70	80
16	Raymond ID	95	55	60	70	80
17	St. Mary River ID	100	55	60	70	80
18	Taber ID	100	55	60	70	80
19	Oldman River PI-Area A	85	55	60	70	80
20	Oldman River PI-Area B	95	55	60	70	80
21	South Saskatchewan River (Alb) PI	100	55	60	70	80
22	South Saskatchewan River ID	100	55	60	70	80
23	Saskatoon SEWS System	100	55	60	70	80
24	South Saskatchewan River WUD-Area A	100	55	60	70	80
25	South Saskatchewan River WUD-Area B	100	55	60	70	80
26	Swift Current Creek WUD	100	55	60	70	80
27	South Sask. River (Sask) PI-Area A	100	55	60	70	80
28	South Sask. River (Sask) PI-Area B	100	55	60	70	80
29	South Sask. River (Sask) PI-Area C	100	55	60	70	80
30	Swift Current Creek PI	100	55	60	70	80
31	Battle River PI-Area A	85	55	60	70	80
32	Battle River PI-Area B	85	55	60	70	80
33	Battle River PI-Area C	90	55	60	70	80
34	Eagle Creek PI	100	55	60	70	80
-	North Saskatchewan River PI-Area A	-	-	-	-	-
-	North Saskatchewan River PI-Area B	-	-	-	-	-
35	North Saskatchewan River PI-Area C	80	55	60	70	80
36	North Saskatchewan River PI-Area D	85	55	60	70	80
37	North Saskatchewan River PI-Area E	85	55	60	70	80
38	Saskatchewan River PI	85	55	60	70	80

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*ID - Irrigation District(s); WUD - Water Users District(s); PI - Private Irrigation.

TABLE 3.7

IRRIGATION SCENARIO DATA -
CROP, SOIL AND IRRIGATION TYPE DISTRIBUTIONS

Irrigation Area		Crops (% of Area)			Soils (% of Area)				Irrigation Types (% of Area)			
No.	Name*	Grains	Forages	Specialties	Light	Medium	Medium Heavy	Heavy	Furrow	Border Dike	Wheel Roll	Center Pivot
1	Red Deer PI-Area A	45.0	45.0	10.0	-	50	50	-	10	10	40	40
2	Red Deer PI-Area B	45.0	45.0	10.0	-	50	50	-	10	10	40	40
3	Red Deer PI-Area C	45.0	45.0	10.0	-	50	50	-	10	10	40	40
4	Red Deer PI-Area D	45.0	45.0	10.0	-	50	50	-	10	10	40	40
5	Red Deer PI-Area E	45.0	45.0	10.0	-	50	50	-	10	10	40	40
6	Western ID	38.6	52.4	9.0	-	-	100	-	8	8	30	54
7	Bow River ID	68.6	18.4	13.0	-	50	50	-	15	15	50	20
8	Eastern ID	56.0	41.1	2.9	-	25	-	75	18	18	40	24
9	Bow River PI-Area A	45.0	45.0	10.0	-	50	50	-	10	10	40	40
10	Bow River PI-Area B	45.0	45.0	10.0	-	50	50	-	10	10	40	40
11	Bow River PI-Area C	45.0	45.0	10.0	-	50	50	-	10	10	40	40
12	Lethbridge Northern ID	70.0	25.0	5.0	-	-	-	100	3	3	14	80
13	Mountain View, Leavitt and Aetna ID	10.0	88.0	2.0	-	-	50	50	44	44	7	5
14	United ID	10.1	88.5	1.4	-	-	-	100	20	20	40	20
15	Magrath ID	55.4	39.0	5.6	-	-	-	100	25	25	40	10
16	Raymond ID	74.5	23.2	2.3	-	-	-	100	20	20	45	15
17	St. Mary River ID	68.1	17.5	14.4	-	20	60	20	10	10	30	50
18	Taber ID	59.7	16.5	23.8	-	50	50	-	10	10	50	30
19	Oldman River PI-Area A	45.0	45.0	10.0	-	50	50	-	10	10	40	40
20	Oldman River PI-Area B	45.0	45.0	10.0	-	50	50	-	10	10	40	40
21	South Saskatchewan River (Alb) PI	45.0	45.0	10.0	-	50	50	-	10	10	40	40
22	South Saskatchewan River ID	77.7	17.9	4.4	-	50	50	-	17	17	16	50
23	Saskatoon SEWS System	65.0	25.0	10.0	-	50	50	-	10	10	40	40
24	South Saskatchewan River WUD-Area A	40.0	55.0	5.0	-	50	50	-	0	20	50	30
25	South Saskatchewan River WUD-Area B	40.0	55.0	5.0	-	50	50	-	0	20	50	30
26	Swift Current Creek WUD	25.0	65.0	10.0	-	50	50	-	25	25	25	25
27	South Sask. River (Sask) PI-Area A	45.0	45.0	10.0	-	50	50	-	10	10	40	40
28	South Sask. River (Sask) PI-Area B	45.0	45.0	10.0	-	50	50	-	10	10	40	40
29	South Sask. River (Sask) PI-Area C	45.0	45.0	10.0	-	50	50	-	10	10	40	40
30	Swift Current Creek PI	25.0	65.0	10.0	-	50	50	-	10	10	40	40
31	Battle River PI-Area A	35.0	55.0	10.0	-	-	100	-	5	5	45	45
32	Battle River PI-Area B	35.0	55.0	10.0	-	-	100	-	10	70	10	10
33	Battle River PI-Area C	45.0	45.0	10.0	-	-	100	-	0	0	70	30
34	Eagle Creek PI	45.0	45.0	10.0	-	-	100	-	10	20	40	30
-	North Saskatchewan River PI-Area A	-	-	-	-	-	-	-	-	-	-	
-	North Saskatchewan River PI-Area B	-	-	-	-	-	-	-	-	-	-	
35	North Saskatchewan River PI-Area C	35.0	55.0	10.0	-	-	100	-	15	15	35	35
36	North Saskatchewan River PI-Area D	35.0	55.0	10.0	-	-	100	-	10	10	40	40
37	North Saskatchewan River PI-Area E	50.0	35.0	15.0	-	-	100	-	5	5	60	30
38	Saskatchewan River PI	45.0	45.0	10.0	-	-	100	-	0	5	75	20

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*ID - Irrigation District(s); WUD - Water Users District(s); PI - Private Irrigation.

TABLE 3.8

IRRIGATION SCENARIO DATA -
IRRIGATED AREAS, CROP IRRIGATION LEVELS
AND DELIVERY EFFICIENCIES, BASE CASE, 1982

Irrigation Area		Irrigated Area (ha)	Crop Irrigation Level (%)			Delivery Efficiency (%)	Delivery Evaporative Losses (%)
No.	Name*		Grains	Forages	Specialties		
1	Red Deer PI-Area A	355	40	40	40	85	15
2	Red Deer PI-Area B	710	40	40	40	85	15
3	Red Deer PI-Area C	2 130	40	40	40	85	15
4	Red Deer PI-Area D	355	40	40	40	85	15
5	Red Deer PI-Area E	3 550	40	40	40	85	15
6	Western ID	18 180	40	40	40	45	40
7	Bow River ID	57 000	40	40	40	65	50
8	Eastern ID	97 250	25	25	25	55	30
9	Bow River PI-Area A	510	40	40	40	85	15
10	Bow River PI-Area B	3 060	40	40	40	85	15
11	Bow River PI-Area C	1 530	40	40	40	85	15
12	Lethbridge Northern ID	42 760	25	25	25	70	30
13	Mountain View, Leavitt and Aetna ID	4 160	15	15	15	55	30
14	United ID	4 070	15	15	15	55	30
15	Magrath ID	4 460	15	15	15	65	0
16	Raymond ID	9 640	15	15	15	65	30
17	St. Mary River ID	108 870	30	30	30	75	30
18	Taber ID	27 250	40	40	40	80	30
19	Oldman River PI-Area A	3 270	40	40	40	85	15
20	Oldman River PI-Area B	7 630	40	40	40	85	15
21	South Saskatchewan River (Alb) PI	10 400	40	40	40	85	15
22	South Saskatchewan River ID	14 850	40	40	40	85	50
23	Saskatoon SEWS System	6 100	40	40	40	85	50
24	South Saskatchewan River WUD Area A	2 760	40	40	40	80	30
25	South Saskatchewan River WUD Area B	400	40	40	40	80	30
26	Swift Current Creek WUD	3 630	40	40	40	80	30
27	South Sask. River (Sask) PI-Area A	10 000	40	40	40	85	15
28	South Sask. River (Sask) PI-Area B	3 360	40	40	40	85	15
29	South Sask. River (Sask) PI-Area C	3 340	40	40	40	85	15
30	Swift Current Creek PI	3 500	40	40	40	85	15
31	Battle River PI-Area A	600	40	40	40	85	15
32	Battle River PI-Area B	3 300	40	40	40	85	15
33	Battle River PI-Area C	300	40	40	40	85	15
34	Eagle Creek PI	400	40	40	40	85	15
-	North Saskatchewan River PI-Area A	-	-	-	-	-	-
-	North Saskatchewan River PI-Area B	-	-	-	-	-	-
35	North Saskatchewan River PI-Area C	400	40	40	40	85	15
36	North Saskatchewan River PI-Area D	1 600	40	40	40	85	15
37	North Saskatchewan River PI-Area E	2 300	40	40	40	85	15
38	Saskatchewan River PI	1 600	40	40	40	85	15
	TOTAL	465 580					

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*ID - Irrigation District(s); WUD - Water Users District(s); PI - Private Irrigation.

TABLE 3.9

IRRIGATION SCENARIO DATA -
IRRIGATED AREAS, CROP IRRIGATION LEVELS
AND DELIVERY EFFICIENCIES, COMMITTED SCENARIO, 1991

Irrigation Area		Irrigated	Crop Irrigation Level (%)			Delivery	Delivery
No.	Name*	Area (ha)	Grains	Forages	Specialties	Efficiency (%)	Evaporative Losses (%)
1	Red Deer PI-Area A	400	50	50	50	85	15
2	Red Deer PI-Area B	800	50	50	50	85	15
3	Red Deer PI-Area C	10 450	50	50	50	85	15
4	Red Deer PI-Area D	400	50	50	50	85	15
5	Red Deer PI-Area E	12 000	50	50	50	85	15
6	Western ID	25 800	50	50	50	65	25
7	Bow River ID	65 000	50	50	50	75	45
8	Eastern ID	108 400	40	40	40	70	15
9	Bow River PI-Area A	550	50	50	50	85	15
10	Bow River PI-Area B	3 350	50	50	50	85	15
11	Bow River PI-Area C	1 700	50	50	50	85	15
12	Lethbridge Northern ID	56 400	40	40	40	85	15
13	Mountain View, Leavitt and Aetna ID	4 300	30	30	30	70	15
14	United ID	8 800	30	30	30	70	15
15	Magrath ID	5 200	30	30	30	75	25
16	Raymond ID	11 800	30	30	30	75	25
17	St. Mary River ID	139 700	50	50	50	85	25
18	Taber ID	29 600	60	60	60	85	25
19	Oldman River PI-Area A	3 600	50	50	50	85	15
20	Oldman River PI-Area B	12 900	50	50	50	85	15
21	South Saskatchewan River (Alb) PI	11 450	50	50	50	85	15
22	South Saskatchewan River ID	22 000	50	50	50	85	35
23	Saskatoon SEWS System	8 900	50	50	50	85	35
24	South Saskatchewan River WUD-Area A	15 100	50	50	50	85	15
25	South Saskatchewan River WUD-Area B	1 400	50	50	50	85	15
26	Swift Current Creek WUD	4 000	50	50	50	85	15
27	South Sask. River (Sask) PI-Area A	12 500	50	50	50	85	15
28	South Sask. River (Sask) PI-Area B	4 200	50	50	50	85	15
29	South Sask. River (Sask) PI-Area C	4 200	50	50	50	85	15
30	Swift Current Creek PI	4 000	50	50	50	85	15
31	Battle River PI-Area A	675	50	50	50	85	15
32	Battle River PI-Area B	3 825	50	50	50	85	15
33	Battle River PI-Area C	425	50	50	50	85	15
34	Eagle Creek PI	475	50	50	50	85	15
-	North Saskatchewan River PI-Area A	-	-	-	-	-	-
-	North Saskatchewan River PI-Area B	-	-	-	-	-	-
35	North Saskatchewan River PI-Area C	500	50	50	50	85	15
36	North Saskatchewan River PI-Area D	2 300	50	50	50	85	15
37	North Saskatchewan River PI-Area E	2 800	50	50	50	85	15
38	Saskatchewan River PI	2 100	50	50	50	85	15
	TOTAL	602 000					

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*ID - Irrigation District(s); WUD - Water Users District(s); PI - Private Irrigation.

TABLE 3.10

IRRIGATION SCENARIO DATA -
IRRIGATED AREAS, CROP IRRIGATION LEVELS
AND DELIVERY EFFICIENCIES, LIKELY FUTURE SCENARIO, 2001

Irrigation Area		Irrigated	Crop Irrigation Level (%)			Delivery	Delivery Evaporative
No.	Name*	Area (ha)	Grains	Forages	Specialties	Efficiency (%)	Losses (%)
1	Red Deer PI-Area A	450	60	60	60	85	15
2	Red Deer PI-Area B	900	60	60	60	85	15
3	Red Deer PI-Area C	10 700	60	60	60	85	15
4	Red Deer PI-Area D	450	60	60	60	85	15
5	Red Deer PI-Area E	28 300	60	60	60	85	15
6	Western ID	33 500	60	60	60	85	15
7	Bow River ID	73 000	60	60	60	85	35
8	Eastern ID	119 500	60	60	60	85	15
9	Bow River PI-Area A	650	60	60	60	85	15
10	Bow River PI-Area B	20 500	60	60	60	85	15
11	Bow River PI-Area C	1 850	60	60	60	85	15
12	Lethbridge Northern ID	70 000	60	60	60	85	15
13	Mountain View, Leavitt and Aetna ID	4 500	50	50	50	85	15
14	United ID	13 500	50	50	50	85	15
15	Magrath ID	6 000	50	50	50	85	25
16	Raymond ID	14 000	50	50	50	85	25
17	St. Mary River ID	170 500	60	60	60	85	25
18	Taber ID	32 000	60	60	60	85	25
19	Oldman River PI-Area A	17 450	60	60	60	85	15
20	Oldman River PI-Area B	13 750	60	60	60	85	15
21	South Saskatchewan River (Alb) PI	12 500	60	60	60	85	15
22	South Saskatchewan River ID	44 300	60	60	60	85	35
23	Saskatoon SEWS System	10 500	60	60	60	85	35
24	South Saskatchewan River WUD-Area A	51 700	60	60	60	85	15
25	South Saskatchewan River WUD-Area B	2 400	60	60	60	85	15
26	Swift Current Creek WUD	4 000	60	60	60	85	15
27	South Sask. River (Sask) PI-Area A	15 600	60	60	60	85	15
28	South Sask. River (Sask) PI-Area B	5 200	60	60	60	85	15
29	South Sask. River (Sask) PI-Area C	5 200	60	60	60	85	15
30	Swift Current Creek PI	4 000	60	60	60	85	15
31	Battle River PI-Area A	825	60	60	60	85	15
32	Battle River PI-Area B	4 775	60	60	60	85	15
33	Battle River PI-Area C	525	60	60	60	85	15
34	Eagle Creek PI	625	60	60	60	85	15
-	North Saskatchewan River PI-Area A	-	-	-	-	-	-
-	North Saskatchewan River PI-Area B	-	-	-	-	-	-
35	North Saskatchewan River PI-Area C	650	60	60	60	85	15
36	North Saskatchewan River PI-Area D	3 150	60	60	60	85	15
37	North Saskatchewan River PI-Area E	3 550	60	60	60	85	15
38	Saskatchewan River PI	2 600	60	60	60	85	15
	TOTAL	803 600					

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*ID - Irrigation District(s); WUD - Water Users District(s); PI - Private Irrigation.

TABLE 3.11

IRRIGATION SCENARIO DATA -
IRRIGATED AREAS, CROP IRRIGATION LEVELS
AND DELIVERY EFFICIENCIES, FUTURE SCENARIO, 2011

Irrigation Area		Irrigated	Crop Irrigation Level (%)			Delivery	Delivery Evaporative
No.	Name*	Area (ha)	Grains	Forages	Specialties	Efficiency (%)	Losses (%)
1	Red Deer PI-Area A	500	60	60	60	85	15
2	Red Deer PI-Area B	1 000	60	60	60	85	15
3	Red Deer PI-Area C	10 950	60	60	60	85	15
4	Red Deer PI-Area D	500	60	60	60	85	15
5	Red Deer PI-Area E	56 750	60	60	60	85	15
6	Western ID	45 200	60	60	60	85	15
7	Bow River ID	97 200	60	60	60	85	35
8	Eastern ID	135 400	60	60	60	85	15
9	Bow River PI-Area A	700	60	60	60	85	15
10	Bow River PI-Area B	23 000	60	60	60	85	15
11	Bow River PI-Area C	2 000	60	60	60	85	15
12	Lethbridge Northern ID	70 000	60	60	60	85	15
13	Mountain View, Leavitt and Aetna ID	6 000	60	60	60	85	15
14	United ID	15 000	60	60	60	85	15
15	Magrath ID	6 000	60	60	60	85	25
16	Raymond ID	14 000	60	60	60	85	25
17	St. Mary River ID	172 000	60	60	60	85	25
18	Taber ID	32 000	60	60	60	85	25
19	Oldman River PI-Area A	22 450	60	60	60	85	15
20	Oldman River PI-Area B	14 650	60	60	60	85	15
21	South Saskatchewan River (Alb) PI	13 800	60	60	60	85	15
22	South Saskatchewan River ID	51 200	60	60	60	85	35
23	Saskatoon SEWS System	10 500	60	60	60	85	35
24	South Saskatchewan River WUD-Area A	51 700	60	60	60	85	15
25	South Saskatchewan River WUD-Area B	2 400	60	60	60	85	15
26	Swift Current Creek WUD	4 000	60	60	60	85	15
27	South Sask. River (Sask) PI-Area A	19 500	60	60	60	85	15
28	South Sask. River (Sask) PI-Area B	6 500	60	60	60	85	15
29	South Sask. River (Sask) PI-Area C	6 500	60	60	60	85	15
30	Swift Current Creek PI	4 000	60	60	60	85	15
31	Battle River PI-Area A	1 025	60	60	60	85	15
32	Battle River PI-Area B	5 975	60	60	60	85	15
33	Battle River PI-Area C	650	60	60	60	85	15
34	Eagle Creek PI	775	60	60	60	85	15
-	North Saskatchewan River PI-Area A	-	-	-	-	-	-
-	North Saskatchewan River PI-Area B	-	-	-	-	-	-
35	North Saskatchewan River PI-Area C	825	60	60	60	85	15
36	North Saskatchewan River PI-Area D	3 950	60	60	60	85	15
37	North Saskatchewan River PI-Area E	4 450	60	60	60	85	15
38	Saskatchewan River PI	3 250	60	60	60	85	15
	TOTAL	916 300					

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*ID - Irrigation District(s); WUD - Water Users District(s); PI - Private Irrigation.

efficiency is field application, as a percentage of diversion, while delivery evaporative loss is a percentage of total delivery losses.

- Irrigated areas (see Tables 3.8, 3.9, 3.10 and 3.11) are based on values estimated in previous phases and on further research undertaken in this phase primarily to develop the 2011 scenario. Details are given below.

  (a) Irrigated areas in Alberta's existing irrigation districts in 2001 have been set at their estimated near-term development values, approximately equivalent to the base case (Scenario 1A) from the South Saskatchewan River Basin Planning Program (SSRBPP) study (References 8 and 9). By 2011, it is assumed that full expansion will have been achieved in all districts in the Oldman basin. In the Bow basin, levels of 50%, 90% and 95% of full expansion are expected in the Western, Bow and Eastern districts respectively. Overall, this is approximately equivalent to a combination of SSRBPP Scenarios 3B and 4B.

  (b) Private irrigated areas in the South Saskatchewan River basin in Alberta are taken as expanding by about 10% every 10 years over the 30-yr scenario sequence. The Little Bow private irrigation area, within the Oldman basin, is an exception and is assumed not to expand [but see also Item (c) below]. Area expansion estimates for private irrigation in the North Saskatchewan River basin in Alberta up to the 2001 scenario are as in previous phases. A further 25% expansion is assumed for the 2011 scenario, in line with the trend of the previous estimates.

  (c) Additional allowances are made within Alberta's private irrigation areas in the South Saskatchewan River basin for the more recent and proposed developments, including

Deadfish, Sheerness and Special Areas in the Red Deer River basin, Blackfoot and Little Bow in the Bow River basin, and Blood and Peigan in the Oldman River basin (see Table 3.12). Of these, the Deadfish and Sheerness developments are taken as complete in 1991, the Blackfoot and Blood projected developments are taken as complete in 2001, and the Peigan projected development is taken as complete in 2011. Overall, the 2011 scenario for these developments is approximately equivalent to a combination of SSRBPP Scenarios 2B and 3B.

(d) In Saskatchewan, full near-term development of the South Saskatchewan River Irrigation District, East Side, is taken as complete in 1991. The West Side development as presently projected is taken as complete in 2001, and a further potential extension (Reference 14) is taken as complete in 2011. Similarly, full near-term development of areas served from the Saskatoon South-East Water Supply System (SSEWSS) is taken as complete in 1991, with the exception of the Blackstrap area which is taken as complete in 2001 (see Table 3.13).

(e) Irrigated areas in Saskatchewan's Water Users Districts, in the South Saskatchewan River basin, are set as in Phase VI, with no further expansion projected beyond 2011 (see Table 3.13). Some of the existing districts, including those supplied from Swift Current Creek, were at or close to full development in 1982. A steady growth rate is applied to other existing districts to reach full development in 2001. Newly proposed district development (Reference 13) is taken as achieving the near-term potential by 1991 and the full potential by 2001. It is tentatively assumed that organized irrigation development in Saskatchewan beyond 2011 will shift to the Qu'Appelle basin, requiring diversions as discussed in Section 3.4.1.

TABLE 3.12

NEW AND/OR MINOR IRRIGATION AREAS - ALBERTA PORTION OF BASIN, ASSUMED DEVELOPMENT

	Irrigated Area (ha)			
Name	**1982**	**1991**	**2001**	**2011**
Sheerness/Deadfish	0	8100	8 100	8 100
Special Areas	0	8100	24 000	52 000
Blackfoot	0	0	4 000	4 000
Little Bow	0	0	12 800	15 000
Blood	0	0	10 000	10 000
Peigan	0	0	3 500	8 100
Ross Creek	Very minor, not accounted for separately			

TABLE 3.13

IRRIGATION AREAS - SASKATCHEWAN PORTION OF BASIN, ASSUMED DEVELOPMENT

	Irrigated Area (ha)			
Name	1982	1991	2001	2011
East Side (Outlook)	14 850	20 000	20 000	20 000
West Side (Conquest)	0	2 000	24 300	31 200
SSEWSS	6 100	8 900	8 900	8 900
Blackstrap	0	0	1 600	1 600
Chesterfield Flats	290	300	300	300
Miry Creek	650	650	650	650
Riverhurst	0	3 200	10 700	10 700
Thunder Creek-Mortlach*	0	2 000	12 400	12 400
Grainland	1 050	2 650	7 250	7 250
Bridgeford-Tugaske*	0	800	8 100	8 100
Luck Lake	0	2 700	7 500	7 500
Macrorie	770	2 800	4 800	4 800
French Flats	160	400	600	600
Moon Lake	240	1 000	1 800	1 800
North Waldeck	630	700	700	700
Rush Lake*	2 400	2 600	2 600	2 600
Herbert*	600	700	700	700

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*Located outside of basin but supplied from basin.

(f) Irrigated areas under private irrigation in the Saskatchewan River basin in Saskatchewan are taken as expanding by about 25% every 10 years over the 30-yr scenario sequence. This does not apply to private irrigation in the Swift Current Creek basin, which was at or close to full development in 1982. It should be noted that significant downward adjustments have been made in this phase to previous assumptions concerning private irrigation areas in the Eagle Creek basin. Unrealistically, high deficits had been estimated for this basin from previous scenario evaluations. It became apparent from research during the present phase that a large portion of the assumed irrigated area actually corresponded to the South Saskatchewan basin and was included elsewhere.

3.4.4 - Energy Project Water Use

- Projections for thermal and hydroelectric energy generating plants on-line for the scenario years have been updated and extended in this phase, based on discussions with power utilities in Alberta and Saskatchewan (see Tables 3.14 and 3.15). Information was available from Phase VI to estimate plant specific water use data for steam-thermal plants; hence, it was not necessary to apply default coefficients.

- Projected special new energy projects on-line for the 1991, 2001 and 2011 scenarios include coal, oil and uranium mining and production facilities (see Table 3.16). Recently available information provided by IW/L (Reference 11) was used to update and extend the previously prepared projections.

TABLE 3.14

STEAM-THERMAL PLANT SCENARIO DATA

	Scenario Years On Stream	Supply Node		Return Node	
Name		No.	ID	No.	ID
Wabamum 1-4	1982	25	05DF001	25	05DF001
	1991				
	2001				
	2011				
Sundance 1-6	1982	25	05DF001	25	05DF001
	1991				
	2001				
	2011				
Rossdale 2-4 & 7-10	1982	25	05DF001	25	05DF001
Rossdale 8-10	1991				
Rossdale 9,10	2001				
	2011				
Battle River 1-5	1982	20	05FC001	20	05FC001
	1991				
	2001				
	2011				
Clover Bar 1-4	1982	25	05DF001	25	05DF001
	1991				
	2001				
	2011				
Medicine Hat 3,4,6,7	1982	7	05AJ001	7	05AJ001
	1991				
	2001				
	2011				
Keephills 1,2	1991	25	05DF001	25	05DF001
Keephills 1-4	2001				
Keephills 1-6	2011				
Sheerness 1,2	1991	11	05CE001	13	05CH007
Sheerness 1-3	2001				
	2011				
Genesee 1,2	1991	25	05DF001	25	05DF001
Genesee 1-3	2001				
Genesee 1-5	2011				

Table 3.14
Steam-Thermal Plant Scenario Data - 2

Name	Scenario Years On Stream	Supply Node No.	Supply Node ID	Return Node No.	Return Node ID
Queen Elizabeth	1982 1991 2001 2011	18	05HG001	18	05HG001

TABLE 3.15

HYDROELECTRIC PLANT SCENARIO DATA

Name	Scenario Years On Stream	Supply Node No.	Supply Node ID	Flow Factor
Kananaskis	1982 1991 2001 2011	4	05BH004	0.72
Horseshoe	1982 1991 2001 2011	4	05BH004	0.64
Ghost	1982 1991 2001 2011	4	05BH004	0.85
Barrier	1982 1991 2001 2011	4	05BH004	0.15
Cascade	1982 1991 2001 2011	4	05BH004	0.08
Spray	1982 1991 2001 2011	4	05BH004	0.13
Three Sisters	1982 1991 2001 2011	4	05BH004	0.04
Rundle	1982 1991 2001 2011	4	05BH004	0.14
Bearspaw	1982 1991 2001 2011	4	05BH004	0.74

Table 3.15
Hydroelectric Plant Scenario Data - 2

Name	Scenario Years On Stream	Supply Node No.	Supply Node ID	Flow Factor
Interlakes	1982 1991 2001 2011	4	05BH004	0.04
Pocaterra	1982 1991 2001 2011	4	05BH004	0.07
Big Bend	1982 1991 2001 2011	24	05DD005	1.00
Big Horn	1982 1991 2001 2011	23	05DC001	0.35
Coteau Creek	1982 1991 2001 2011	17	DIEFRES	1.00
Squaw Rapids	1982 1991 2001 2011	29	05KJ001	0.76
Nipawin	1991 2001 2011	29	05KJ001	0.76

TABLE 3.16

SPECIAL ENERGY PROJECTS SCENARIO DATA

Name	Type	Production Capacity	Water Intake Rate (Mm^3/yr/unit of production)	Consumption (% of intake)	Node No.	Node ID
1991 Committed Scenario						
Sheerness	Coal, Conventional	3.3 Mt/yr	0.320000	25.0	13	05CH007
Genesee	Coal, Conventional	3 Mt/yr	0.320000	25.0	25	05DF001
Cluff Lake	Uranium, High Grade	2000 t/yr	0.000250	10.0	29	05KJ001
2001 Future Scenario						
Sheerness	Coal, Conventional	3.3 Mt/yr	0.320000	25.0	13	05CH007
Genesee	Coal, Conventional	3 Mt/yr	0.320000	25.0	25	05DF001
Elk Point	Oil, Heavy	26 600 bbl/d	0.000438	90.0	26	05EF001
Lloydminster	Oil, Refining	54 000 bbl/d	0.000040	75.0	26	05EF001
Cluff Lake	Uranium, High Grade	2000 t/yr	0.000250	10.0	29	05KJ001
2011 Future Scenario						
Shaughnessy	Coal, Conventional	2.7 Mt/yr	0.320000	25.0	3	05AD007
Kipp	Coal, Conventional	1 Mt/yr	0.320000	25.0	3	05AD007
Turbo Resources Ltd.	Oil, Refining	31 500 bbl/d	0.000040	75.0	4	05BH004
Medicine Hat	Methanol, Coal	0.44 Mt/yr	3.020000	16.7	7	05AJ001
Open Pit Coal Mine	Coil, Conventional	9 Mt/yr	0.320000	25.0	10	05CC002
Sheerness	Coal, Conventional	3.3 Mt/yr	0.320000	25.0	13	05CH007
Rose Lynn	Coal, Conventional	1.1 Mt/yr	0.320000	25.0	13	05CH007
Battrum	Oil, Heavy	16 000 bbl/d	0.000438	90.0	16	05HD039
Paintearth	Coal, Conventional	1 Mt/yr	0.320000	25.0	21	05FE001

Table 3.18

Special Energy Projects Scenario Data - 2

Name	Type	Production Capacity	Water Intake Rate (Mm^3/yr/unit of production)	Consumption (% of intake)	Node No.	Node ID
Hardisty Upgrading	Oil, Refining	1600 bbl/d	0.000040	75.0	21	05FE001
Genesee	Coal, Conventional	3 Mt/yr	0.320000	25.0	25	05DF001
Highvale	Coal, Conventional	12.8 Mt/yr	0.320000	25.0	25	05DF001
Whitewood	Coal, Conventional	0.7 Mt/yr	0.320000	25.0	25	05DF001
Esso Resources	Oil, Heavy	50 000 bbl/d	0.000438	90.0	25	05DF001
Int'l Technologies	Oil, Heavy	20 000 bbl/d	0.000438	90.0	25	05DF001
Gulf Canada	Oil, Refining	40 000 bbl/d	0.000040	75.0	25	05DF001
Texaco Canada	Oil, Refining	4000 bbl/d	0.000040	75.0	25	05DF001
Elk Point	Oil, Heavy	28 600 bbl/d	0.000438	90.0	26	05EF001
Lloydminster	Oil, Heavy	23 800 bbl/d	0.000438	90.0	26	05EF001
Lloydminster	Oil, Heavy	10 200 bbl/d	0.000438	90.0	26	05EF001
Lloydminster	Oil, Oil Sands	15 000 bbl/d	0.000256	90.0	26	05EF001
Lloydminster	Oil, Refining	54 000 bbl/d	0.000040	75.0	26	05EF001
Lindbergh	Oil, Oil Sands	4700 bbl/d	0.000256	90.0	26	05EF001
Shell Canada-Husky Oil	Oil, Refining	80 000 bbl/d	0.000040	75.0	26	05EF001
Imperial Oil	Oil, Refining	45 000 bbl/d	0.000040	75.0	26	05EF001
Lloydminster	Oil, Heavy	13 700 bbl/d	0.000438	90.0	28	05GG001
Texas Gulf Stream	Oil, Heavy	410 bbl/d	0.000438	90.0	28	05GG001
Husky Oil	Oil, Refining	10 000 bbl/d	0.000040	75.0	28	05GG001
Rabbit Lake	Uranium, High Grade	2000 t/yr	0.000250	10.0	28	05GG001
Cluff Lake	Uranium, High Grade	2000 t/yr	0.000250	10.0	29	

3.4.5 - Minimum Flow Requirements

- Apportionment flows at the Alberta/Saskatchewan boundary are set at the natural flows corresponding to the border nodes. The minimum flow requirements are set at 50% of the apportionment flows.

- Apportionment flows at the Saskatchewan/Manitoba boundary are set at the natural flows corresponding to the border node, less 50% of those corresponding to the Alberta/Saskatchewan border nodes. The minimum flow requirements are then 50% of these resultant flows.

- Minimum flow releases at modeled reservoirs are set as shown in Table 3.3.

- Minimum flows at intermediate nodes in the network have not been specified for the following reasons.

  (a) Reservoir releases are deemed to have covered in-stream requirements.

  (b) Apportionment requirements are met monthly by cutbacks in consumptive use as required, thus ensuring that streamflows are generally maintained at least at 50% of the natural flows.

  (c) There are no confirmed officially designated minimum flow requirements, other than for reservoir releases.

  (d) Minimum flow requirements specified in previous phases, taken from the SSRBPP study (Reference 8), were seen, in general, to be unrealistically severe.

3.5 - Scenario Evaluation Results

The results of the evaluations of the 1982 base case and the 2001 and 2011 future scenarios are presented in this section. The scenarios are illustrated by graphs produced with the model. The two graph types selected as the principal and most useful ones for describing evaluation results are

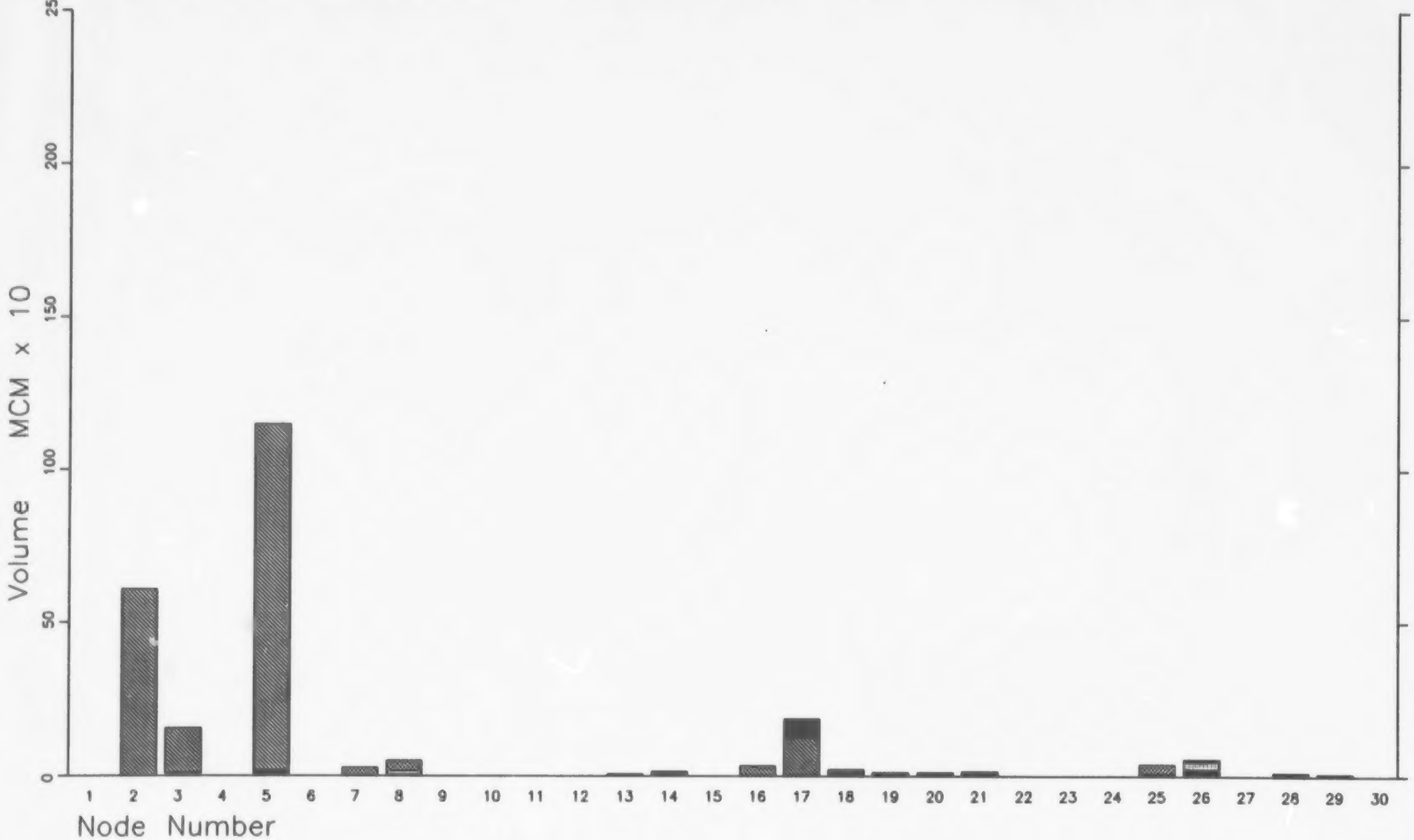
- demanded annual consumption by usage group
- demanded total consumption as percentage of availability.

Figures 3.4, 3.5 and 3.6 show the magnitude of the various average annual consumption demands at each node of the network for each scenario evaluated.

The second graph type shows the corresponding frequencies of total monthly occurrences of the four supply availability classes: large deficit, small deficit, small surplus and large surplus. The graph for each evaluated scenario has been produced as in Figures 3.7, 3.8 and 3.9.

Corresponding details of the evaluation results are summarized below in list form, grouped according to the two major topics of consumption demands and supply availability. At reservoirs, instream use requirements are reflected in the selected lower rule curve elevations. In assessment of the capability of the basin to satisfy the demand for water, supply availability must be examined in parallel with the ability to satisfy instream use requirements. If supply availability is adequate but instream uses are violated then a system failure may occur.

DEMANDED ANNUAL CONSUMPTION BY USAGE GROUP



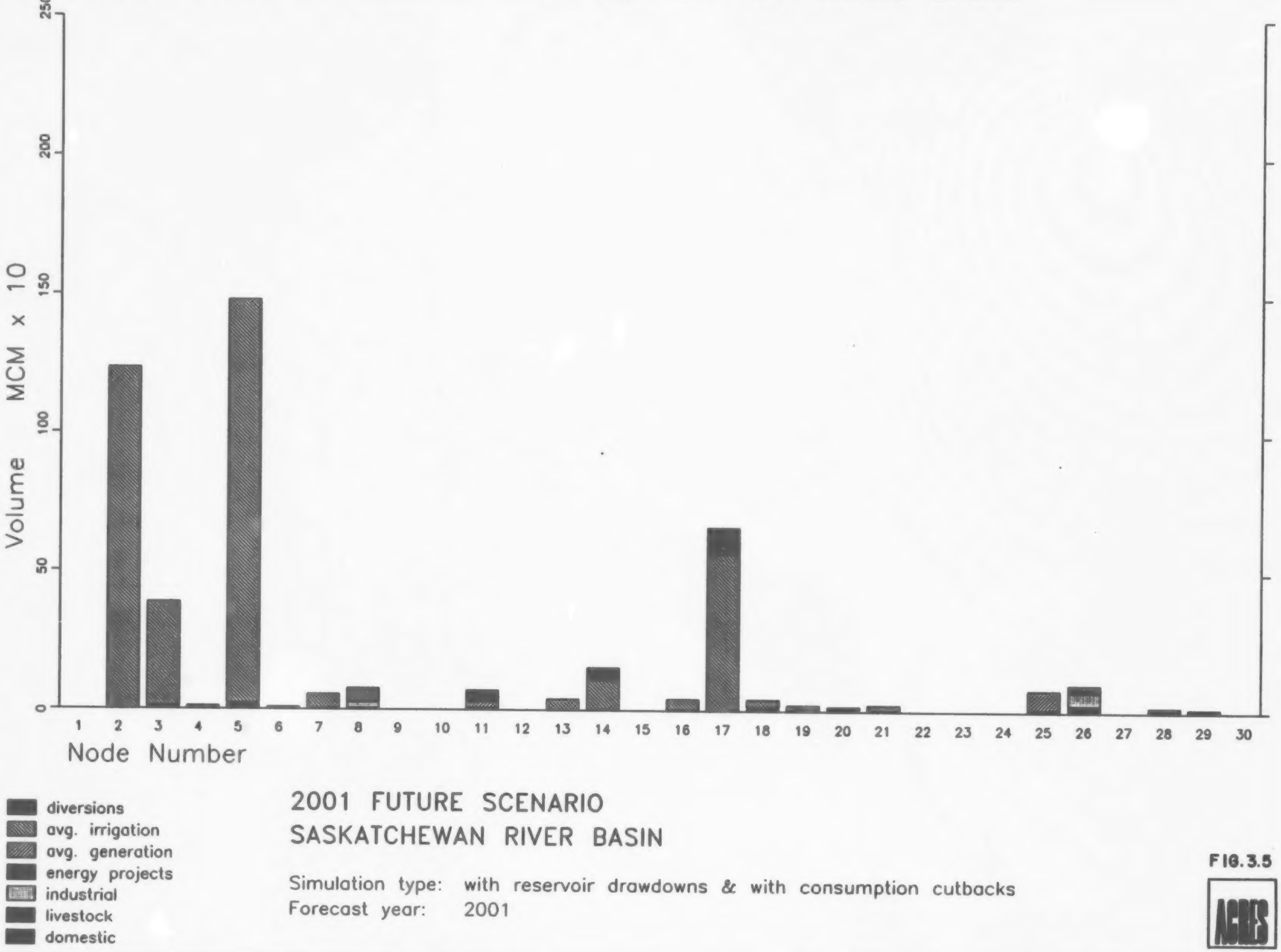
1982 BASE CASE
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG.3.4

ACRES

DEMANDED ANNUAL CONSUMPTION BY USAGE GROUP



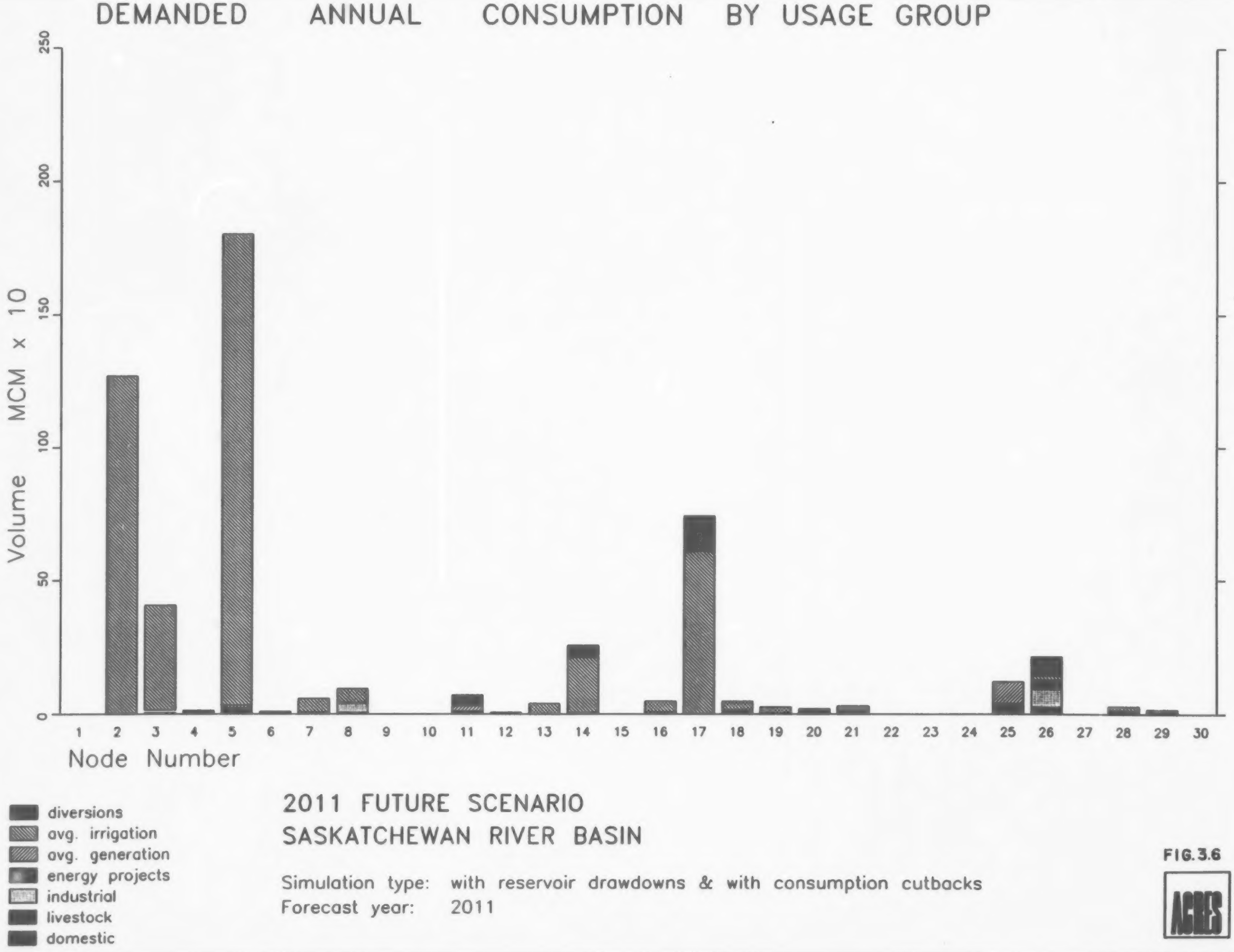
2001 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2001

FIG.3.5

ACRES

DEMANDED ANNUAL CONSUMPTION BY USAGE GROUP



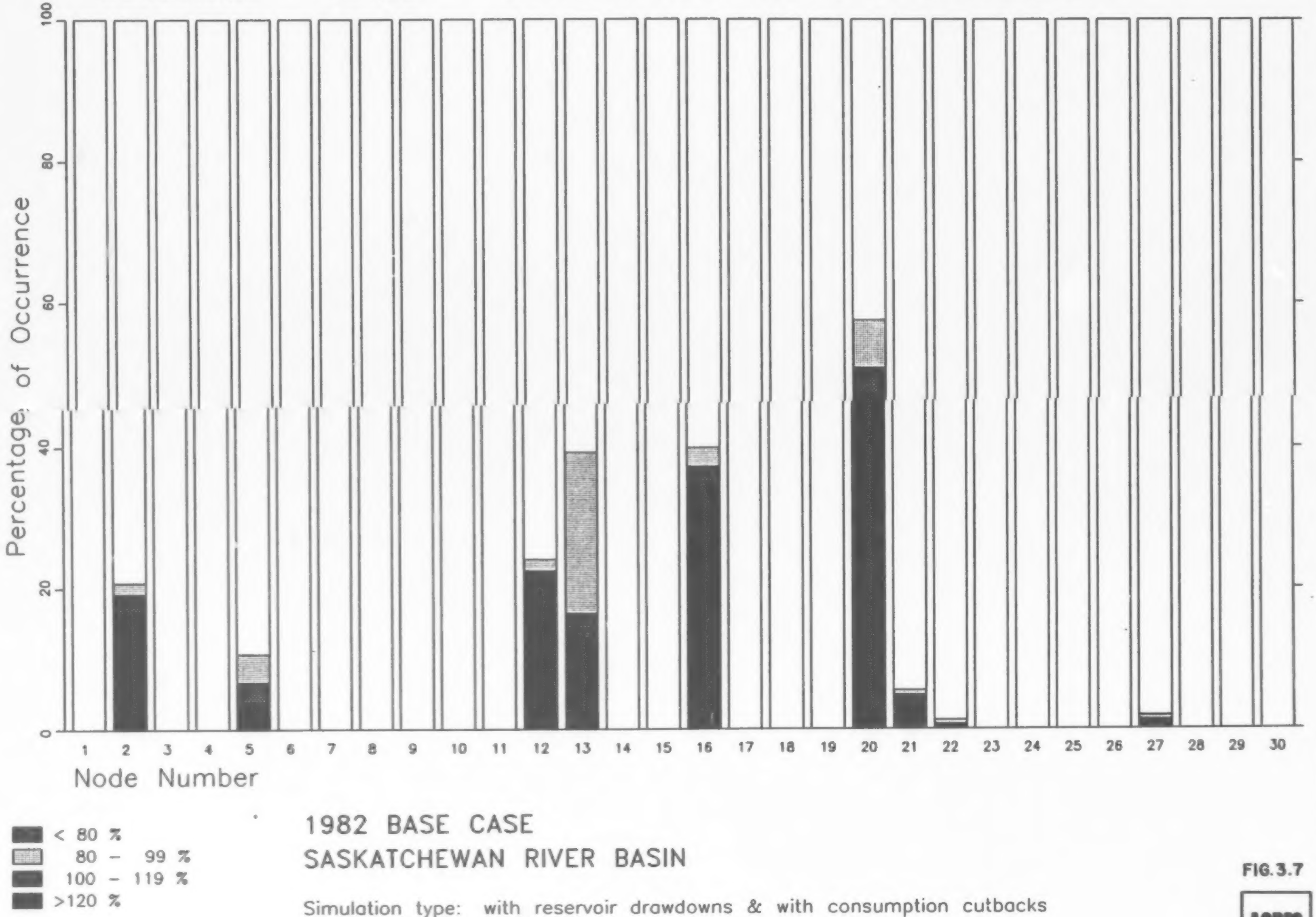
2011 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2011

FIG.3.6

ACRES

DEMANDED TOTAL CONSUMPTION AS % OF AVAILABILITY



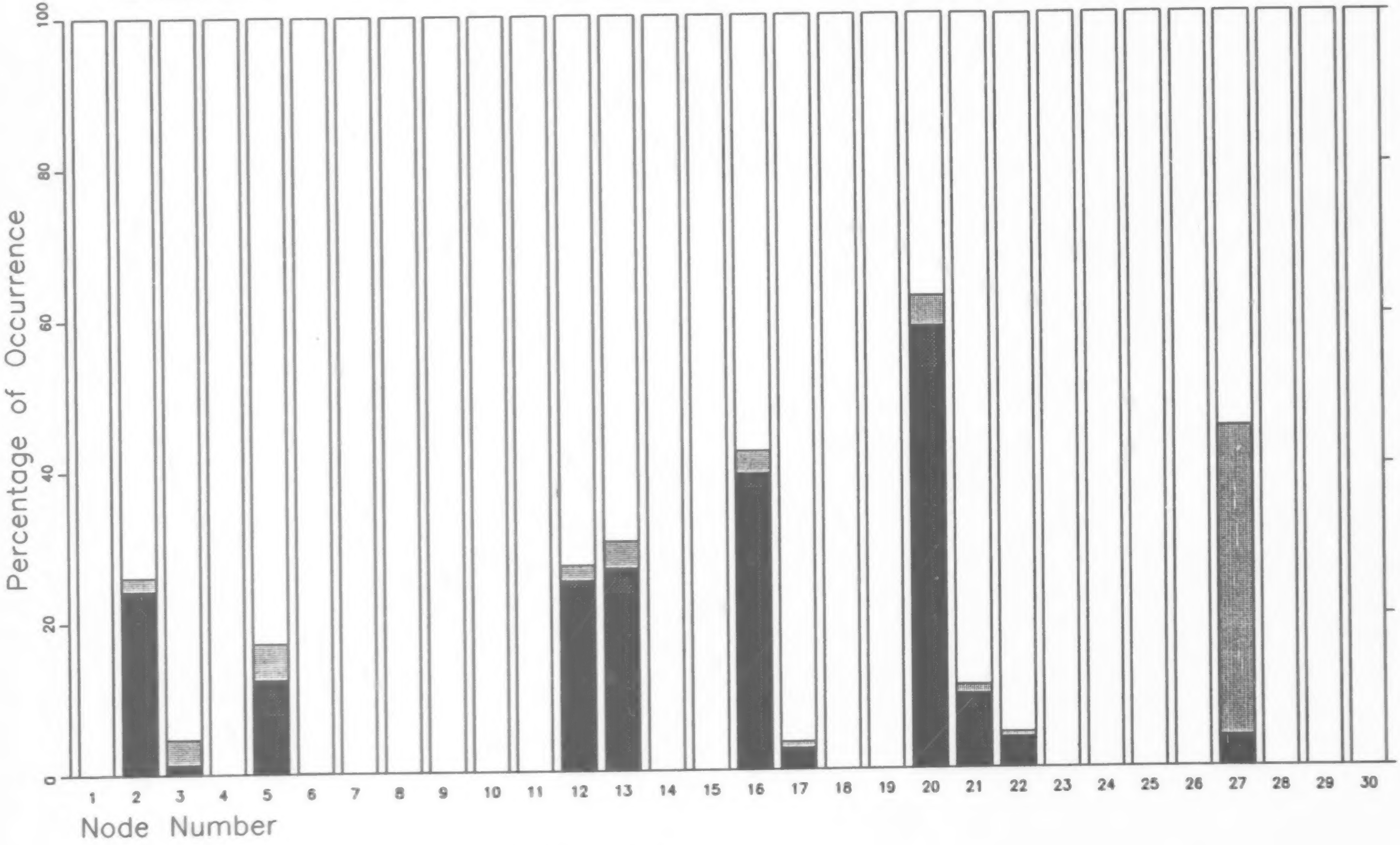
1982 BASE CASE
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG. 3.7

ACRES

DEMANDED TOTAL CONSUMPTION AS % OF AVAILABILITY



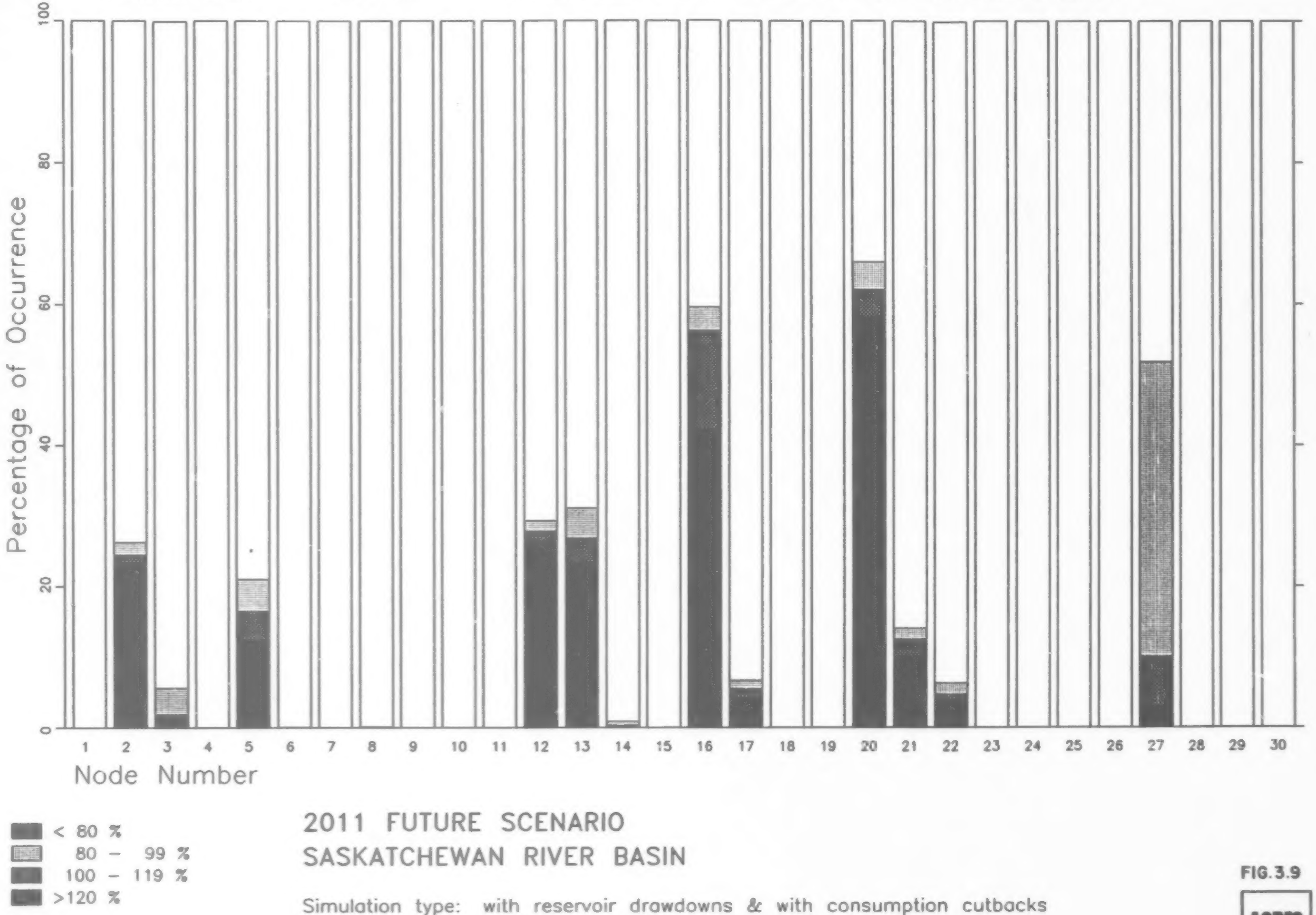
2001 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2001

FIG. 3.8

ACRES

DEMANDED TOTAL CONSUMPTION AS % OF AVAILABILITY



2011 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2011

FIG.3.9

ACRES

3.5.1 - Consumption Demands

(a) Irrigation Demands

- Irrigation demands, as expected, dominate those of all other water usage groups.

- The largest irrigation demands correspond to the major irrigation areas supplied from the Oldman River and its tributaries above Lethbridge (Nodes 2 and 3), from the Bow River between Calgary and Bassano (Node 5), and from Lake Diefenbaker (Node 17). Consumption demand increases over 1982 levels at these locations are indicated as follows.

Subbasin Node Name	No.	Consumption Demand Increases (% over 1982 values) 2001	2011
Waterton/St. Mary	2	100	110
Lethbridge	3	150	160
Bassano	5	29	57
Diefenbaker	17	340	380

- Other significant but much smaller irrigation demands correspond to the lower Oldman River and upper South Saskatchewan River basins (Nodes 7 and 8), to the Berry Creek and lower Red Deer River basins (Nodes 13 and 14), and to the Red Deer River basin at the Buffalo Lake diversion (Node 4). At these locations, consumption increases between 1982 and 2001 are not shown to be greatly significant, except in the lower Oldman River and Red Deer River basins. Those latter increases correspond largely to developments occurring between 1991 and 2001. Consumption continues to increase at all of the nodes discussed above in the period from 2001 to 2011.

(b) Thermal Power Generation Demands

- The greatest demand for thermal power generation corresponds to the Edmonton area in the North Saskatchewan River basin (Node 25), where a consumption increase of about 100% is shown between 1982 and 2001. This corresponds largely to development of the Keephills and Genesee plants.

- Also of note is the water demand shown for the Sheerness plant in 1991 and 2001, supplied from the Red Deer River (Node 11).

- Between 2001 and 2011, additional thermal power generation demand is added at Keephills and Genesee (Node 25) and at the Blackfoot plant (Node 5).

(c) Domestic, Industrial and Energy Project Demands

- Domestic water demands of some note are shown for the Calgary and Edmonton areas (Nodes 5 and 26), with relatively small increases estimated between 1982 and 2011.

- Industrial and energy project demands of some note are shown for the Edmonton to Lloydminster portion of the North Saskatchewan River basin (Node 26), increasing by about 80% between 1982 and 2001. The total increase from 1982 to 2011 is 150%. This corresponds largely to oil industry developments.

(d) Diversion Demands

- The largest diversion demand corresponds to the Qu'Appelle diversion from Lake Diefenbaker (Node 17), which is shown as increasing by 60% from 1982 to 2001 and by 130% from 1982 to 2011.

- Also significant compared with other demands in 2001 and 2011 are the Buffalo Lake and Sheerness/Deadfish diversions from the Red Deer River (Nodes 11 and 14). The second of these, however, is only significant from the viewpoint of the Berry Creek subbasin (Node 13), which receives the diversion. This is because return flows after use drain back into the Red Deer River above Bindloss (Node 14). Both diversions are in place for 2001 and do not increase between 2001 and 2011.

3.5.2 - Supply Availability

(a) Base Case, 1982

- At the Waterton/St. Mary and Bassano nodes in Alberta (Nodes 2 and 5) and the Lake Diefenbaker node in Saskatchewan (Node 17), where the largest irrigation demands are located, the occurrence of supply deficits with respect to consumption demands for the 1982 case are as shown below. Modeling of the Waterton/St. Mary reservoir has reduced the supply deficits at the Lethbridge node which were identified in the Phase VI study. Note that while availability problems may not exist at a reservoir, failure can also occur due to the inability of the reservoir to satisfy the instream use requirements reflected in the lower rule curve levels.

Subbasin Node Name	No.	Frequency of Occurrence (%) All Deficits Monthly	Seasonal	Large Deficits* Monthly	Seasonal
Waterton/ St. Mary	2	19	9	17	0
Lethbridge	3	0	0	0	0
Bassano	5	7	4	4	0
Diefenbaker	17	0	0	0	0

In studies carried out for previous phases of the project, a 20% frequency of occurrence of large seasonal deficits for irrigation water use was considered to be critical. By this criterion, supply availability in these subbasins in 1982 was satisfactory.

- Frequent monthly supply deficits are indicated for the small streams included in the model network, as seen below.

Stream Name	Node No.	Frequency of Occurrence (%) All Deficits Monthly	Seasonal	Large Deficits Monthly	Seasonal
Rosebud River	12	22	0	22	0
Berry Creek	13	16	25	15	16
Swift Current Creek	16	37	9	35	6

The frequency of occurrence of seasonal deficits in the Berry Creek subbasin is seen to have been at a near-critical level in 1982. Demands at these locations are very small, but streamflows are also very low or nonexistent, most notably in winter. The indicated monthly deficits at these nodes represent differences in small numbers divided by small numbers, and it seems clear that the regional perspective of the model and data base is not particularly well suited to water use analysis of the small subbasins. The current data base includes regional data which has been disaggregated to the subbasin level. When assessing water supply problems, this approach yields meaningful results from a regional prospective. However, distortions can appear in the smaller subbasins. In this application the data base [illegible] not adequate for the precise detailed evaluation of these subbasins.

---

*Greater than 20% of supply.

Their incorporation into the larger basins may be an appropriate future modification.

- A similar situation applies to the Battle River basin (Nodes 20, 21 and 22), as seen below.

Battle River Subbasin	Node No.	Frequency of Occurrence (%)			
		All Deficits		Large Deficits	
		Monthly	Seasonal	Monthly	Seasonal
Upper	20	51	16	47	11
Central	21	5	2	4	2
Lower	22	1	0	0	0

The highest indicated occurrence of deficits corresponds to the small upper subbasin (Node 20), while a comparatively infrequent occurrence of deficits is indicated for the central and lower basins (Nodes 21 and 22). In this case, a more appropriate regional representation may be gained in future by combining the upper and central basins into a single basin.

- Elsewhere in the Saskatchewan River basin, at locations along the main stream system, there are no indicated supply deficits for the 1982 case.

- Simulated hydroelectric energy generation for the 1982 case is summarized in Table 3.17.

- Operation of the Lake Diefenbaker reservoir for the 1982 case simulation is seen to be reasonably satisfactory. Monthly reservoir levels below lower rule curve occur 8% of the time overall, and 15% of the time during the irrigation season. Figures 3.10 and 3.11 show the variation of the reservoir water levels over 4-yr periods of wet and dry hydrologic conditions. It should be noted that the reservoir has continued to satisfy the supply availability criteria. However, lower rule curve violations occur much more frequently than supply deficits and indicate that instream uses are not always satisfied.

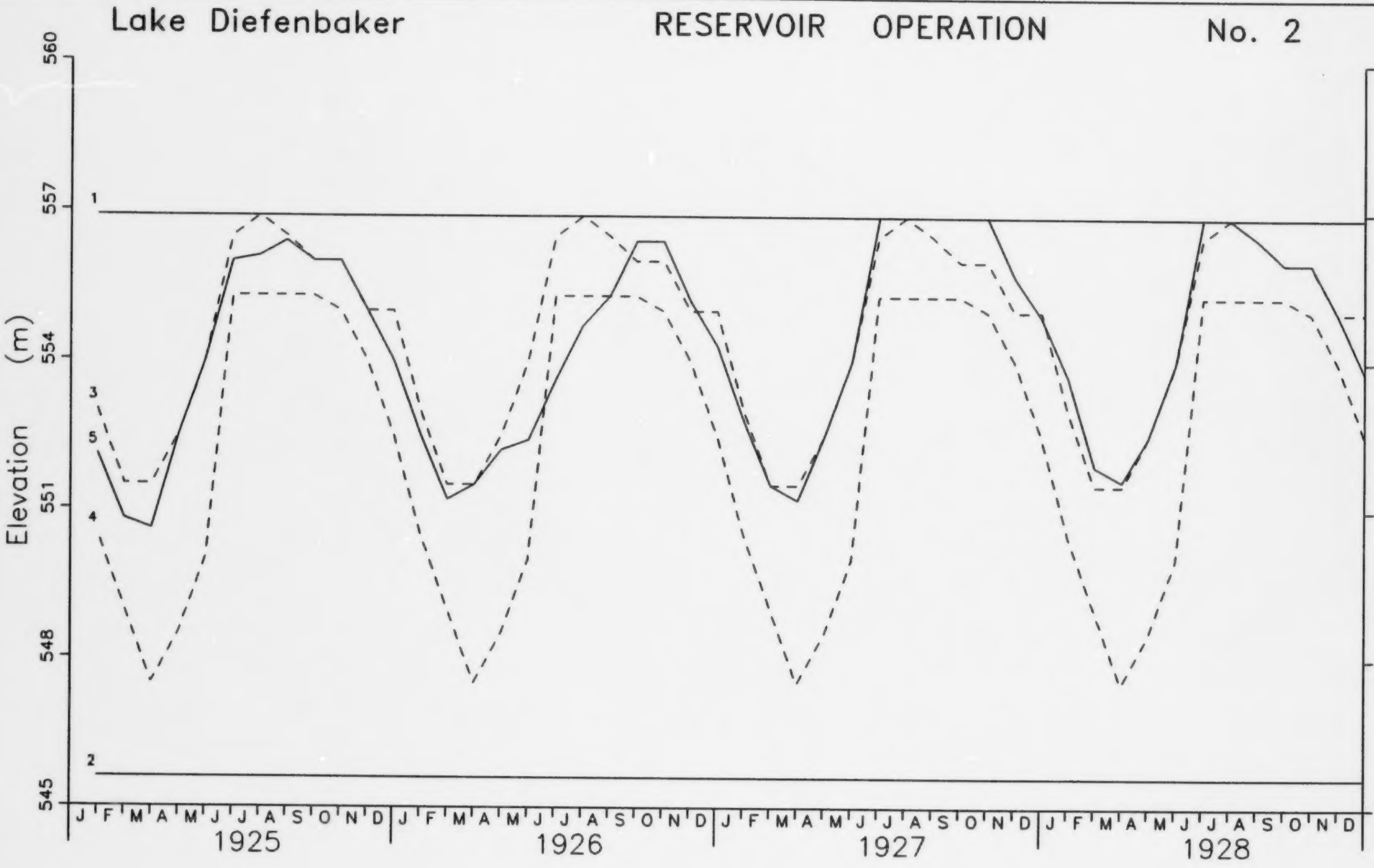
- Operation of the Waterton/St. Mary reservoir for the 1982 case scenario is also satisfactory. Monthly reservoir levels below the lower rule curve occur 12% of the time overall but only 10% of the time during the irrigation season. Figures 3.12 and 3.13 show the variation in reservoir water levels over 4-yr periods of wet and dry hydrologic conditions.

- Figures 3.14 and 3.15 show summaries of reservoir elevation and outflows for the Waterton/St. Mary reservoir. In the case of the summaries, the minimum, target and maximum flows and elevations are defined in an earlier section and vary monthly. Outflows E1 and E2 are the average of the flows above and below in magnitude. Elevation E3 is midway between the maximum and minimum rule curve levels.

TABLE 3.17

SIMULATED AVERAGE HYDROELECTRIC ENERGY GENERATION
BASE CASE, 1982

	Node	Average Energy Generation (GW·h)												
Plant Name	No.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Kananaskis	4	5.8	5.1	5.6	7.2	8.7	12.5	12.7	11.2	8.4	6.8	5.7	5.7	95.4
Horseshoe	4	5.2	4.6	5.0	6.4	7.2	9.3	9.6	9.3	7.2	6.0	5.1	5.1	80.0
Ghost	4	10.7	9.5	10.4	13.3	16.5	28.7	28.5	21.7	15.7	12.5	10.5	10.6	188.5
Barrier	4	2.6	2.3	2.5	3.2	4.0	7.0	7.0	5.3	3.8	3.1	2.6	2.6	46.1
Cascade	4	3.1	2.7	3.0	3.8	4.7	9.0	8.8	6.2	4.5	3.6	3.0	3.0	55.5
Spray	4	13.0	11.6	12.7	16.2	20.0	38.1	37.1	26.4	19.1	15.2	12.8	12.9	235.1
Three Sisters	4	0.3	0.3	0.3	0.4	0.5	0.9	0.8	0.6	0.4	0.3	0.3	0.3	5.3
Rundle	4	4.5	4.0	4.3	5.5	6.9	13.1	12.7	9.1	6.5	5.2	4.4	4.4	80.7
Bearspaw	4	4.5	4.0	4.3	5.5	6.8	10.4	10.6	8.8	6.5	5.2	4.4	4.4	75.4
Interlakes	4	0.5	0.5	0.5	0.6	0.8	1.5	1.5	1.0	0.8	0.6	0.5	0.5	9.3
Pocaterra	4	1.7	1.5	1.7	2.1	2.6	5.0	4.9	3.5	2.5	2.0	1.7	1.7	30.9
Big Bend	24	28.3	25.6	27.8	26.8	29.7	47.5	74.0	61.2	41.9	30.9	27.4	28.3	449.4
Big Horn	23	21.6	19.4	21.3	20.3	21.5	24.8	51.0	57.3	34.7	22.5	20.9	21.6	336.8
Coteau Creek	17	103.2	88.2	74.8	55.8	66.7	68.8	83.6	70.2	56.8	60.9	84.1	88.7	901.8
Squaw Rapids	29	82.1	69.6	63.9	100.5	134.5	106.1	162.1	159.2	122.2	98.6	95.0	80.1	1273.9
TOTAL		287.1	248.8	238.3	267.6	331.0	382.9	505.0	451.0	331.0	273.3	278.3	269.9	3864.2



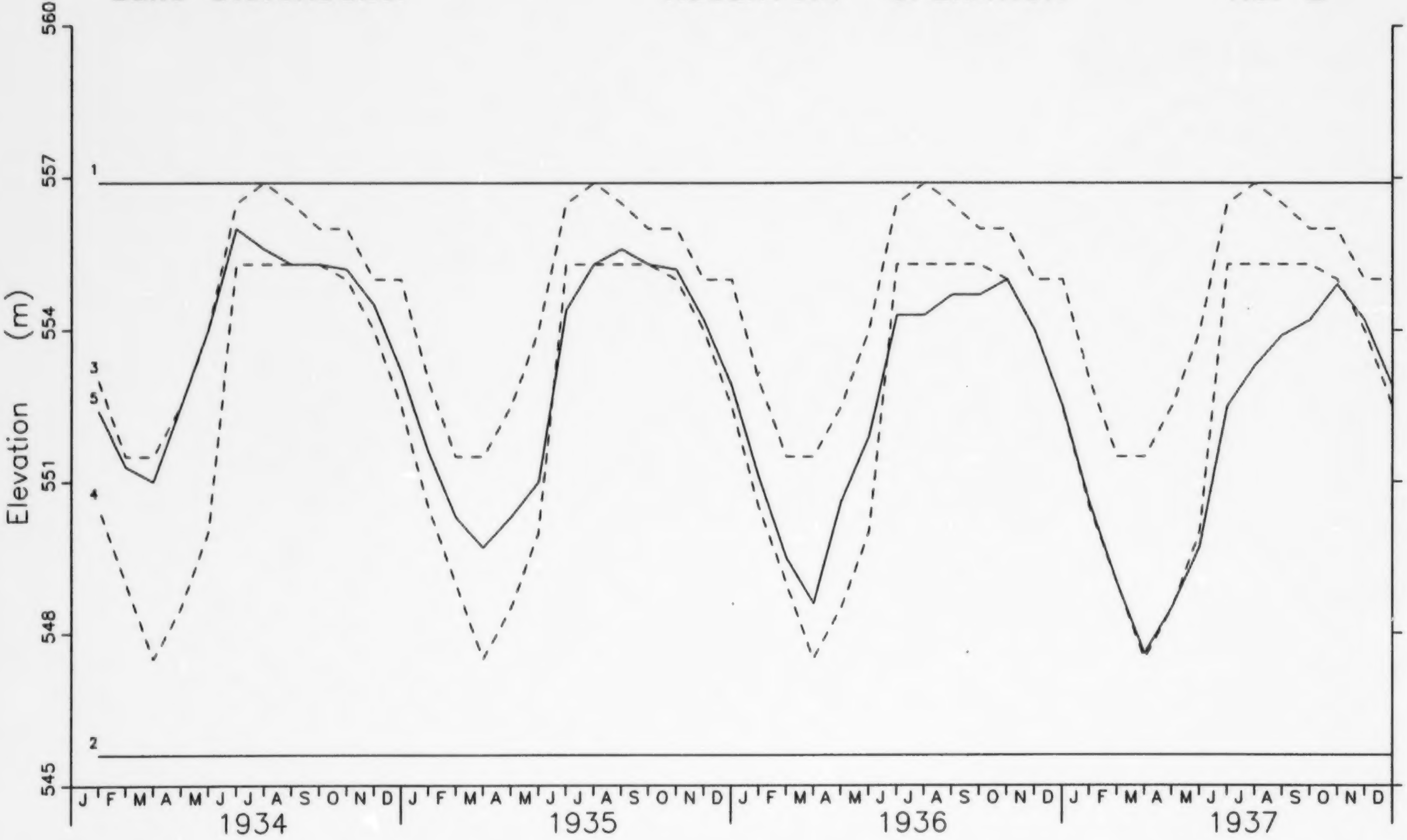
1982 BASE CASE
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG. 3.10

ACRES

Lake Diefenbaker RESERVOIR OPERATION No. 2



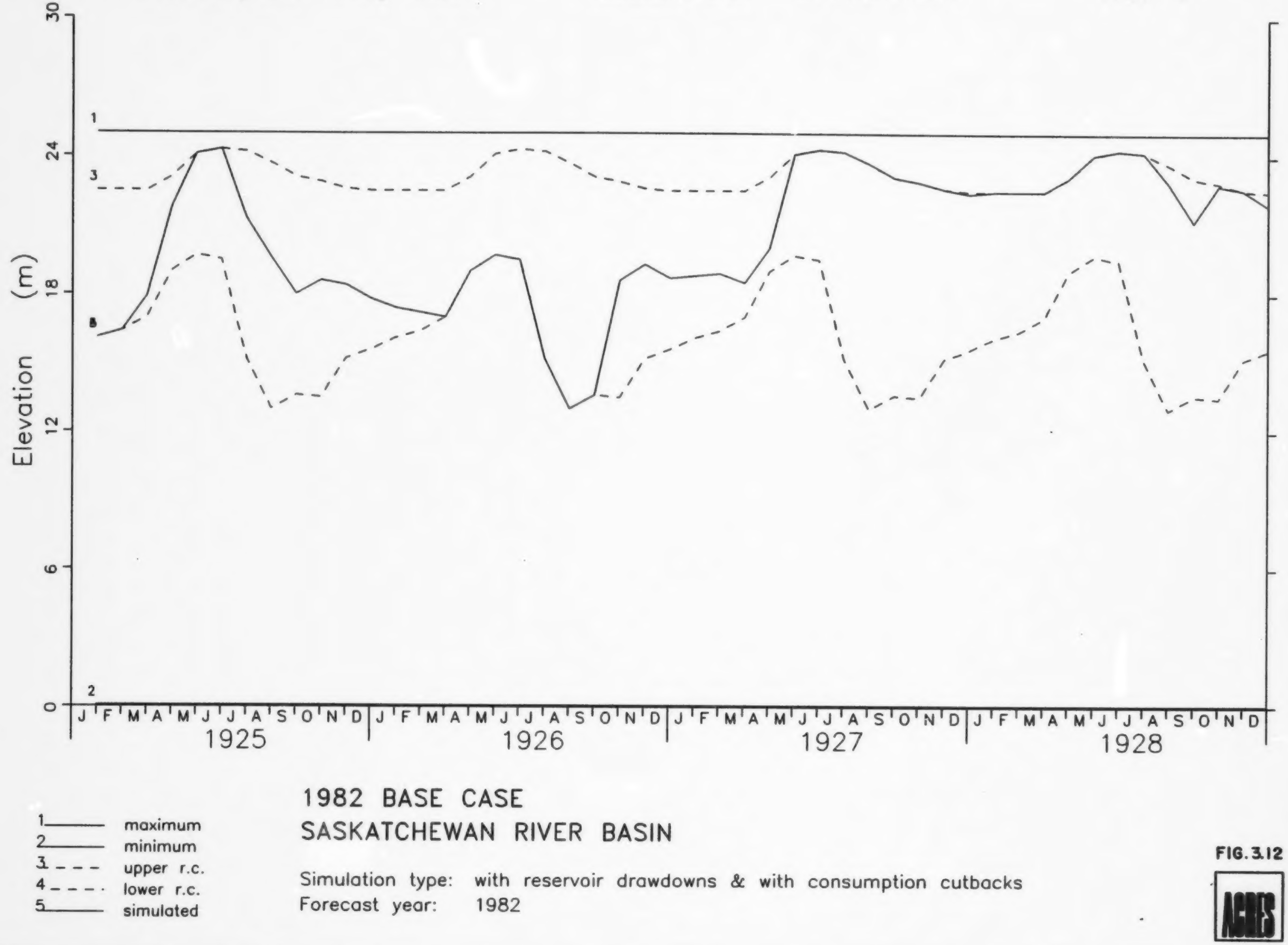
1982 BASE CASE
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG.3.11

ACRES

Waterton/St. Mary Res RESERVOIR OPERATION No. 1



1982 BASE CASE

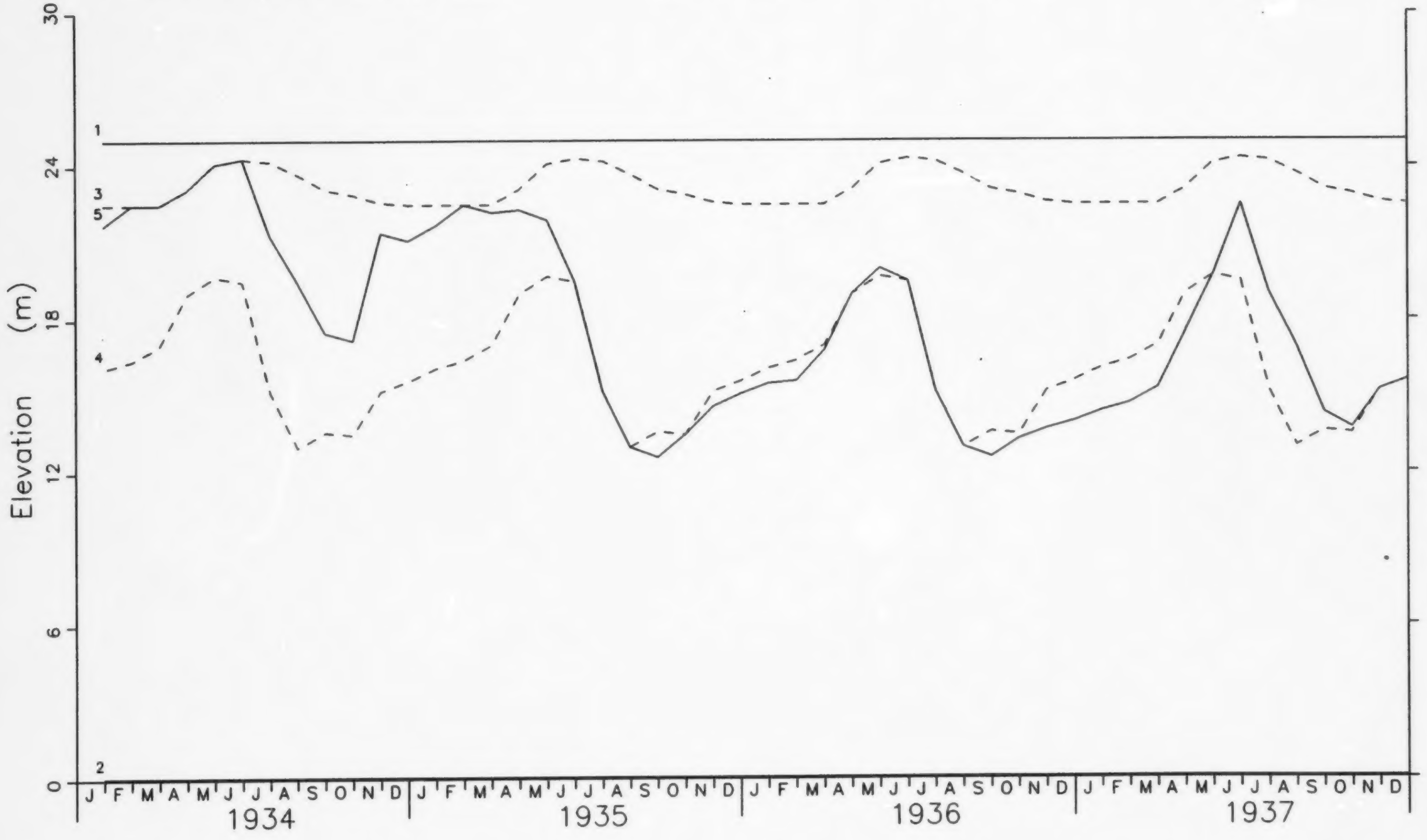
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG. 3.12

ACRES

Waterton/St. Mary Res RESERVOIR OPERATION No. 1



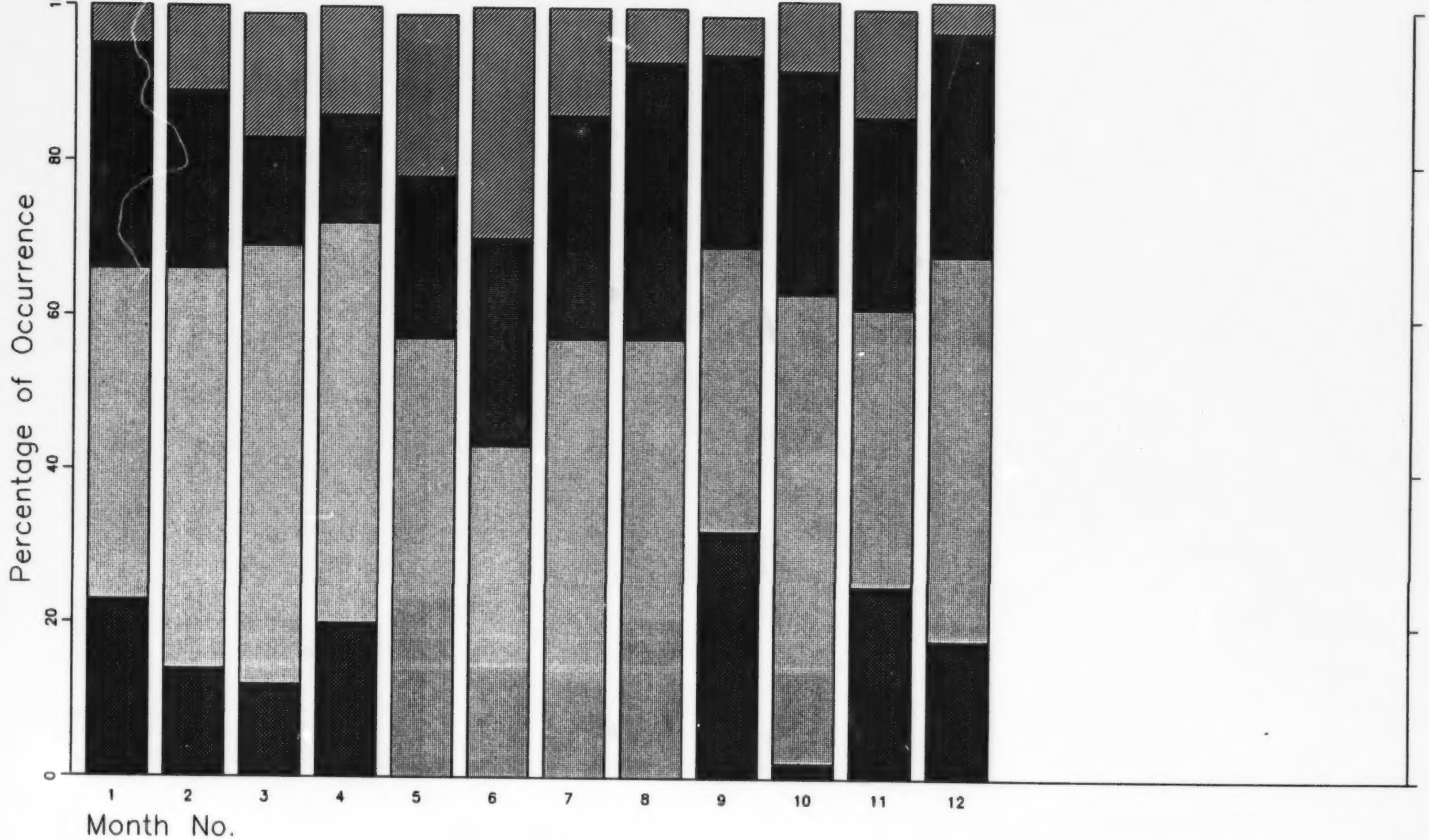
1982 BASE CASE
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG. 3.13

ACRES

Waterton/St. Mary Res RESERVOIR ELEVATION SUMMARY No. 1

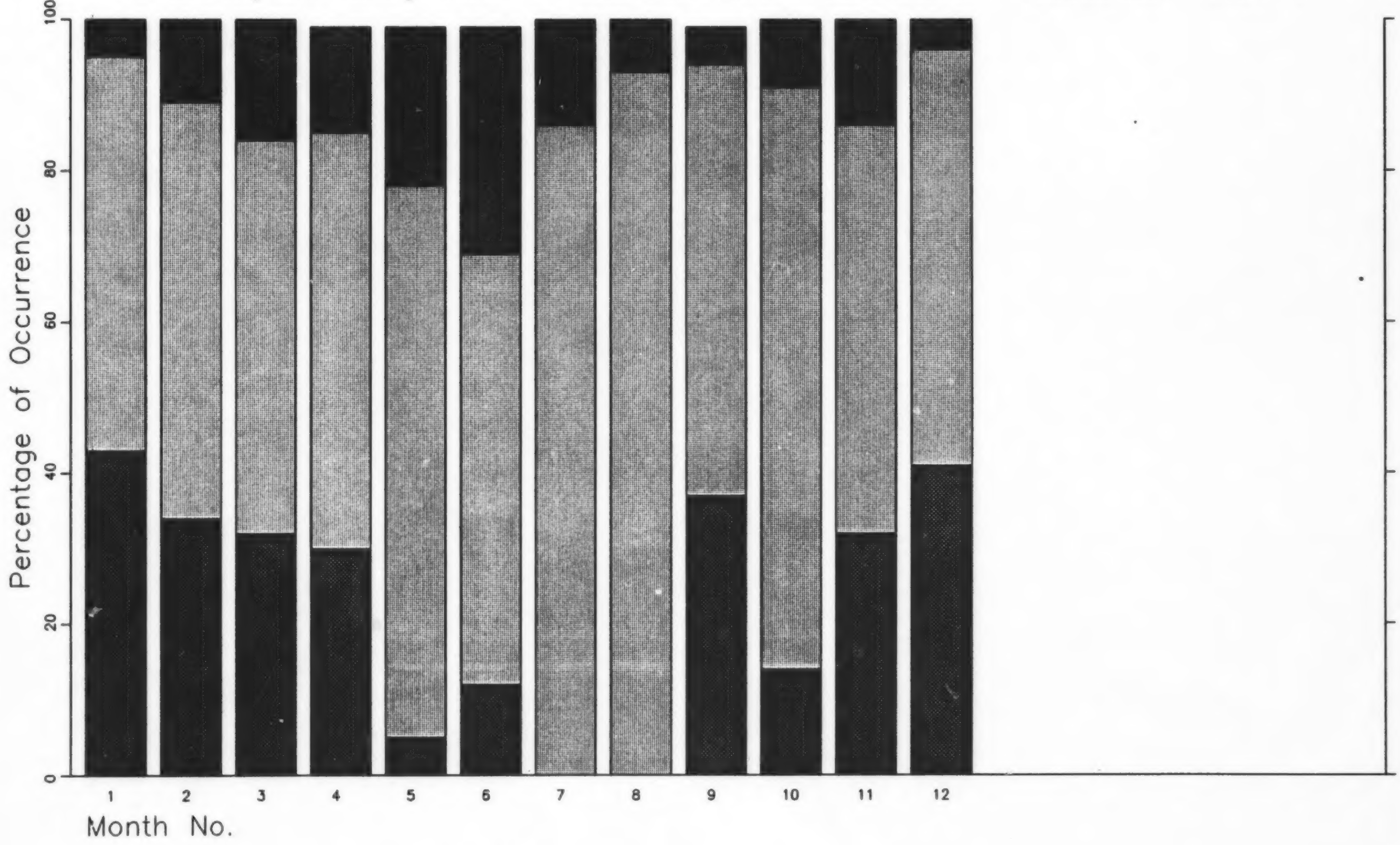


1982 BASE CASE
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG.3.14

Waterton/St. Mary Res RESERVOIR OUTFLOW SUMMARY No. 1



1982 BASE CASE
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG. 3.15

ACRES

- Figures 3.16 and 3.17 show summaries of reservoir elevation and outflow for the Lake Diefenbaker reservoir.

- Of the four provincial boundary locations where apportionment requirements were imposed, only the Battle River (Node 21) was shown to have monthly shortages in outflow. These occurred 7% of the time overall or 18% of the time during the irrigation season, with no shortages outside of the season. Water use cutbacks averaging 15% of demand were needed at these times to satisfy the apportionment requirements. Table 3.18 shows the corresponding distribution of cutback occurrences and amounts by month and by water use sector.

(b) 2001 Future Scenario

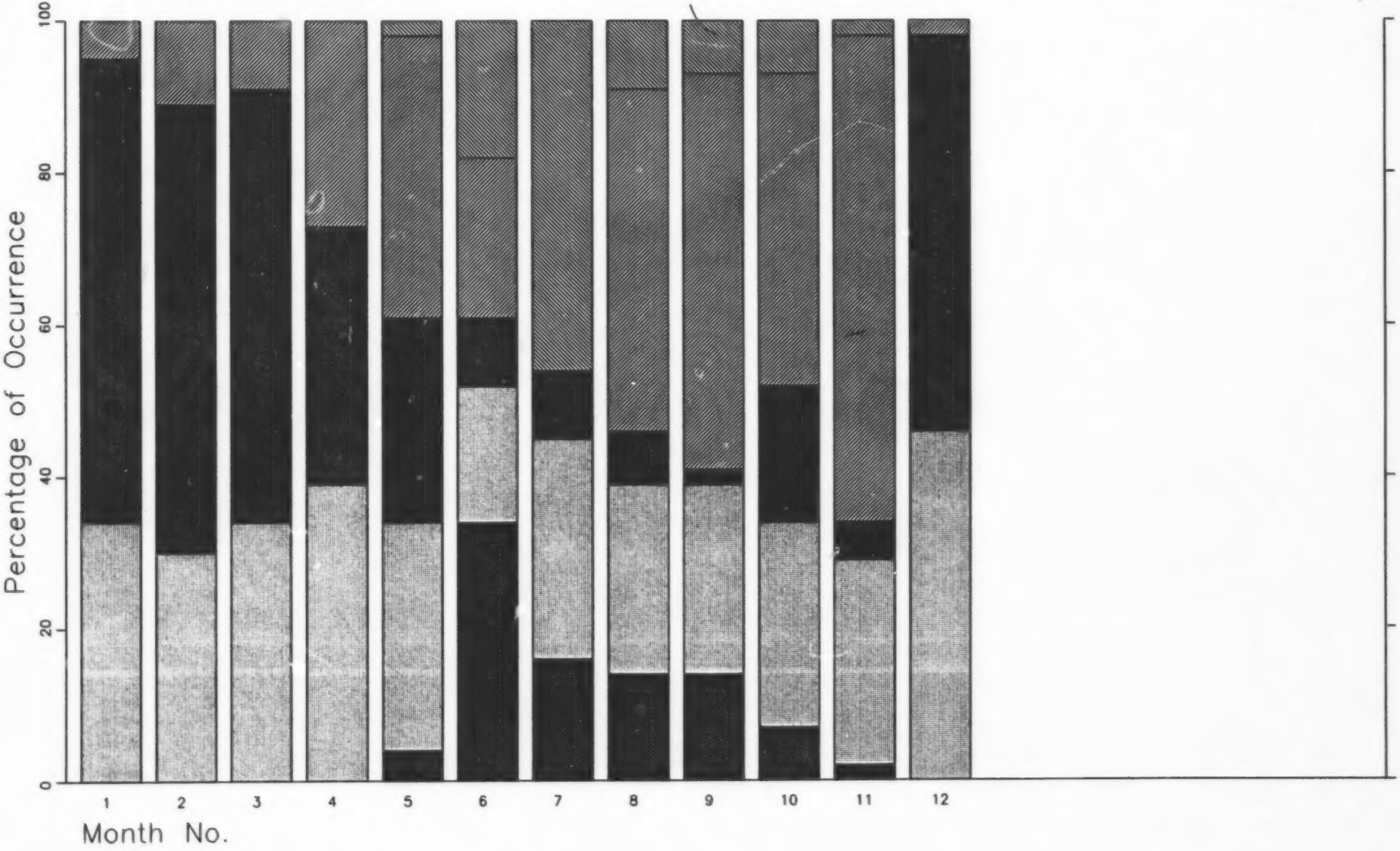
- The indicated supply deficits with respect to consumption demands at the principal irrigation supply nodes for the 2001 scenario are as follows.

Subbasin Node		Frequency of Occurrence (%)			
		All Deficits		Large Deficits	
Name	No.	Monthly	Seasonal	Monthly	Seasonal
Waterton/ St. Mary	2	24	71	23	52
Lethbridge	3	1	0	0	0
Bassano	5	15	14	10	9
Diefenbaker	17	3	0	2	0

Indicated deficits in the Waterton/St. Mary subbasin (Node 2) exceed the deficit criterion for critical water supply constraints. This represents a major deterioration of the 1982 case situation. Conversely, in spite of a similar percentage increase in consumption demands, there is no important deterioration in the deficit situation

Lake Diefenbaker

RESERVOIR ELEVATION SUMMARY No. 2



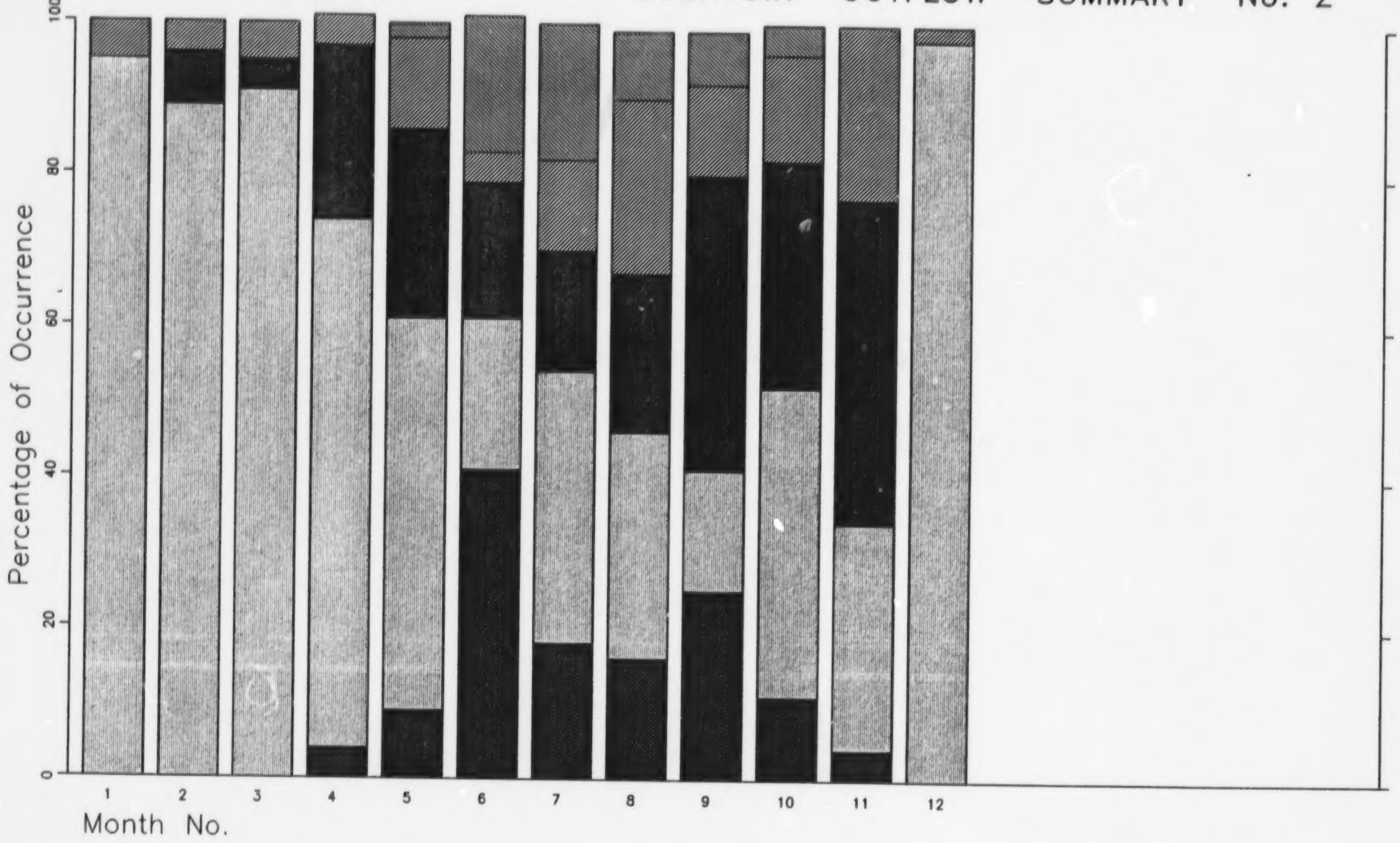
1982 BASE CASE
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG.3.16

ACRES

Lake Diefenbaker RESERVOIR OUTFLOW SUMMARY No. 2



1982 BASE CASE
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG.3.17

ACRES

TABLE 3.18

CONSUMPTION CUTBACKS SUMMARY, BATTLE RIVER BASIN
BASE CASE, 1982

		Consumption Cutbacks Summary		Percentage of Occurrences	
Month	**No.**	**Domestic**	**Livestock**	**Industrial**	**Irrigation**
Jan	56	0.0	0.0	0.0	0.0
Feb	56	0.0	0.0	0.0	0.0
Mar	56	0.0	0.0	0.0	0.0
Apr	56	0.0	0.0	0.0	0.0
May	56	0.0	0.0	0.0	0.0
June	56	3.6	7.1	5.4	7.1
July	56	14.3	23.2	23.2	21.4
Aug	56	21.4	26.8	26.8	25.0
Sept	56	17.9	32.1	25.0	28.6
Oct	56	0.0	0.0	0.0	0.0
Nov	56	0.0	0.0	0.0	0.0
Dec	56	0.0	0.0	0.0	0.0
Season	280	11.4	17.9	16.1	16.4
Annual	672	4.8	7.4	6.7	6.8

		Consumption Cutbacks Summary		Min/Avg/Max Cutbacks (%)	
Month	**No.**	**Domestic**	**Livestock**	**Industrial**	**Irrigation**
Jan	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Feb	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Mar	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Apr	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
May	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
June	56	8.5 / 8.5 / 8.5	10.0 / 10.0 / 10.0	10.0 / 16.7 / 20.0	6.7 / 11.4 / 19.8
July	56	8.5 / 8.5 / 8.5	8.5 / 9.8 / 10.0	10.0 / 22.1 / 40.0	2.0 / 18.0 / 35.0
Aug	56	8.5 / 8.5 / 8.5	9.3 / 10.0 / 10.0	10.0 / 20.8 / 40.0	4.3 / 17.6 / 31.1
Sept	56	1.1 / 7.7 / 8.5	2.2 / 9.5 / 10.0	10.0 / 22.9 / 40.0	1.3 / 16.8 / 32.0
Oct	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Nov	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Dec	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0

indicated for the Lethbridge subbasin (Node 3). This is due largely to the presence and operation of the Oldman reservoir in this scenario. Increased deficit occurrence frequencies are indicated for the Bassano subbasin (Node 5), but these remain acceptably low. The large consumption demand increases at Lake Diefenbaker (Node 17) do not lead to any deficits in this scenario. Explicit modeling of the Waterton/St. Mary reservoir appears to have confirmed the water supply difficulties identified in the Phase VI study. It is known qualitatively that some water supply difficulties have already been experienced in this irrigation system in recent years. Note that while availability problems may not exist at a reservoir, water level problems can occur due to the inability of the reservoir to satisfy the instream use requirements reflected in the lower rule curve levels.

- Supply deficits indicated for the Rosebud River and Swift Current Creek subbasins (Nodes 12 and 16), and the Battle River basin (Nodes 20, 21 and 22), remain essentially similar to those for the 1982 case. This is as expected, given the very minor additional development expected in these basins. Conversely, more frequent large seasonal deficits are indicated in the Eagle Creek subbasin (Node 27), where irrigation consumption demand increases are estimated to be very modest in absolute terms but large in percentage terms. The problem of modeling small subbasins, mentioned previously, may be compounded in this case by insufficient recognition of the effects of associated closed drainage areas on the accuracy of model evaluations. This would apply to several subbasins, and a review of this topic would be an important future task.

- In the Berry Creek subbasin (Node 13), where a large consumption demand increase occurs due to irrigation area developments, the occurrence of seasonal deficits has increased in frequency to a near critical level. This is in spite of the implementation of the Deadfish and Sheerness diversions. Changes in the quantity of diversion flows have a significant effect with the relatively small basin. Indicated monthly deficits in winter continue to have a high frequency of occurrence, as in all the small subbasins that are modeled separately.

- There are no indicated supply deficits at the other main stream locations in the Saskatchewan River basin, in spite of some significant increases in consumption demands.

- Simulated hydroelectric energy generation for this scenario is summarized in Table 3.19. Increases in total generation over the 1982 case values are due to the addition of the Nipawin plant, but consumption demand increases reduce generation at the other downstream plants.

- Lower rule curve violations as simulated at the four reservoirs explicitly modeled in the 2001 scenario are shown below.

	Frequency of Occurrence of Monthly Lower Rule Curve Violations (%)*			
Reservoir	In Year	In Season	June	July
Waterton/ St. Mary	17	14	11	0
Oldman	0	0	0	0
Dickson	38	30	16	20
Diefenbaker	19	36	45	39

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*Calculated as the number of months with simulated violations divided by the number of simulation months, expressed as a percentage.

TABLE 3.19

SIMULATED AVERAGE HYDROELECTRIC ENERGY GENERATION
FUTURE SCENARIO, 2001

	Node	Average Energy Generation (GW·h)												
Plant Name	No.	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Kananaskis	4	5.8	5.1	5.6	7.2	8.7	12.5	12.7	11.2	8.4	6.8	5.7	5.7	95.4
Horseshoe	4	5.2	4.6	5.0	6.4	7.2	9.3	9.6	9.3	7.2	6.0	5.1	5.1	80.0
Ghost	4	10.7	9.5	10.4	13.3	16.4	28.7	28.5	21.7	15.6	12.5	10.5	10.6	188.3
Barrier	4	2.6	2.3	2.5	3.2	4.0	7.0	6.9	5.3	3.8	3.1	2.6	2.6	46.0
Cascade	4	3.1	2.7	3.0	3.8	4.7	9.0	8.8	6.2	4.5	3.6	3.0	3.0	55.5
Spray	4	13.0	11.5	12.7	16.2	20.0	38.1	37.1	26.4	19.1	15.2	12.8	12.9	235.1
Three Sisters	4	0.3	0.3	0.3	0.4	0.4	0.9	0.8	0.6	0.4	0.3	0.3	0.3	5.2
Rundle	4	4.5	4.0	4.3	5.5	6.9	13.1	12.7	9.1	6.5	5.2	4.4	4.4	80.7
Bearspaw	4	4.5	3.9	4.3	5.5	6.8	10.4	10.6	8.8	6.5	5.2	4.4	4.4	75.3
Interlakes	4	0.5	0.5	0.5	0.6	0.8	1.5	1.5	1.0	0.8	0.6	0.5	0.5	9.3
Pocaterra	4	1.7	1.5	1.7	2.1	2.6	5.0	4.9	3.5	2.5	2.0	1.7	1.7	30.9
Big Bend	24	28.3	25.6	27.8	26.8	29.7	47.5	74.0	61.2	41.9	30.9	27.4	28.3	449.4
Big Horn	23	21.6	19.4	21.3	20.3	21.5	24.8	51.0	57.3	34.7	22.5	20.9	21.6	336.8
Coteau Creek	17	101.7	88.1	74.9	53.4	58.2	58.6	57.6	45.1	36.3	48.8	68.4	78.4	769.5
Squaw Rapids	29	80.5	68.9	63.2	99.0	130.7	99.1	151.0	150.8	112.6	92.0	86.3	74.2	1208.3
Nipawin	29	73.4	62.8	57.7	90.3	118.5	90.0	136.5	135.9	102.2	83.6	78.6	67.7	1097.2
TOTAL		357.3	310.7	295.2	354.1	437.0	455.6	604.1	553.4	403.0	338.3	332.4	321.4	4762.9

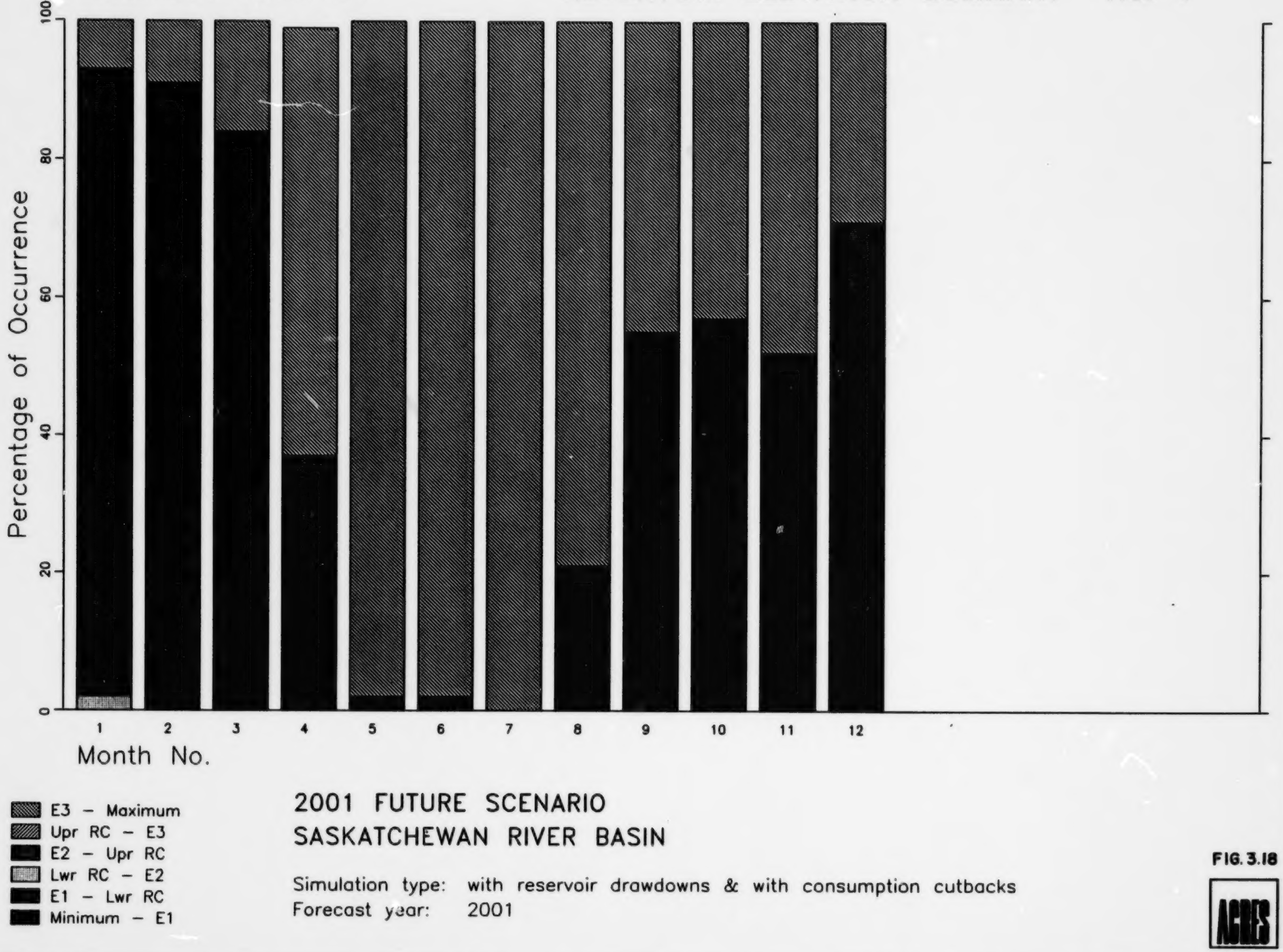
As expected, the Oldman reservoir is easily able to support the estimated consumption demand increases. The Dickson reservoir, on the other hand, has limited regulation capabilities, its prime purpose being flow augmentation in low flow periods. Of the simulated monthly lower rule curve violations, 20% correspond to reservoir failures, all in winter (low flow) months. This is an 8% occurrence over all the simulation months. In contrast, there is an 18% overall occurrence of levels at full supply level, mostly in the early summer months. The Dickson reservoir is quite effective in maintaining minimum winter flow requirements. Lower rule curve violations at Lake Diefenbaker show a modest increase in frequency over the 1982 case violations. During critical instream use months of June and July, there are frequent lower rule curve violations. At the Waterton/St. Mary reservoir, lower rule curve violations occur 17% of the time; however, no reservoir failures occur. The lower rule curve violations show an inability to meet instream use requirements at the reservoirs.

Figures 3.18, 3.19, 3.20 and 3.21 show the elevation summary plots for the four reservoirs modeled. These plots show the monthly distribution and frequency of occurrence of reservoir levels.

- Provincial boundary flow shortages and corresponding water use cutbacks indicated for this scenario are as indicated for the 1982 case, with the Battle River (Node 21) presenting the only problem. Table 3.20 gives the corresponding cutback details.

Oldman Reservoir

RESERVOIR ELEVATION SUMMARY No. 1

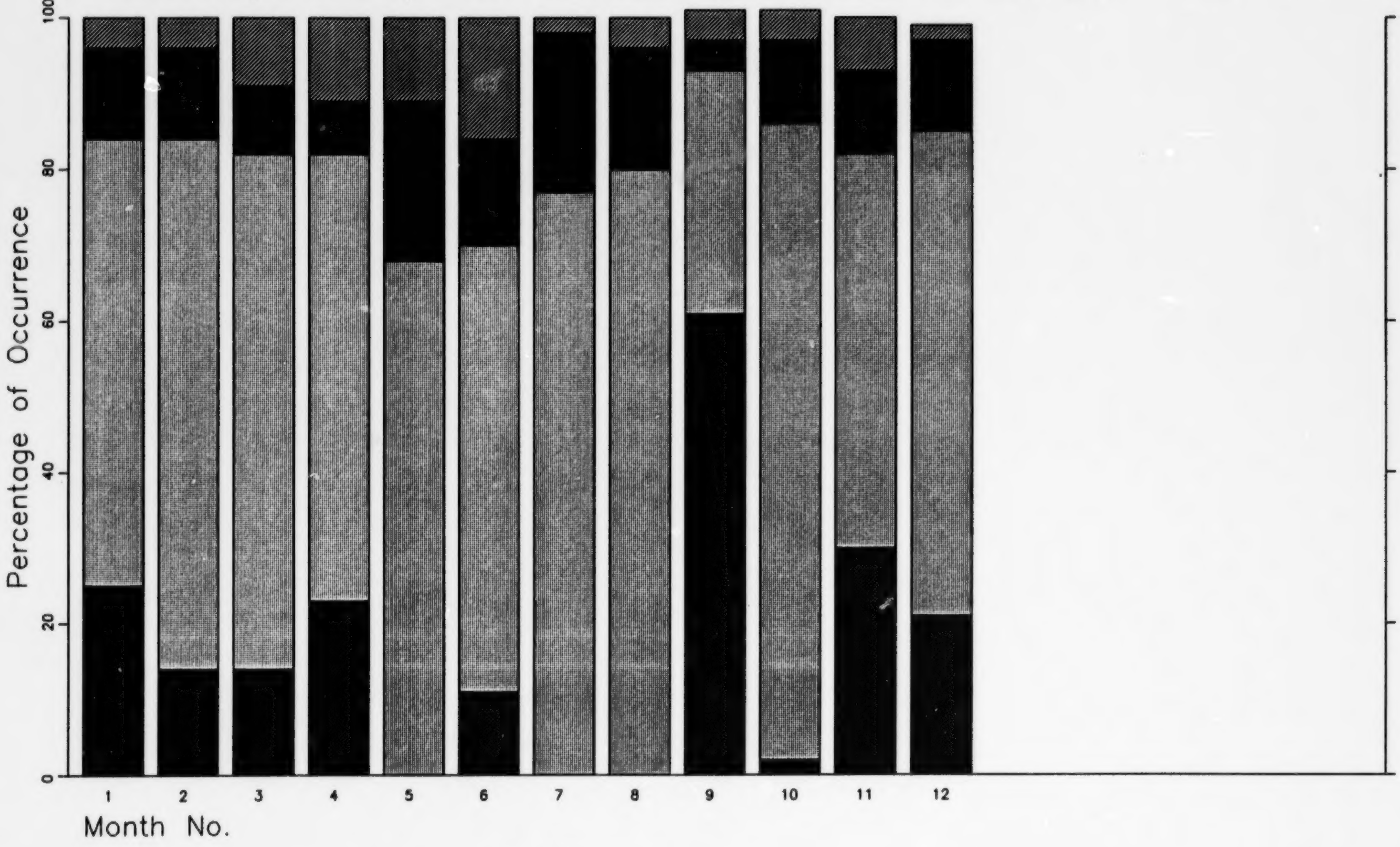


2001 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2001

FIG. 3.18

Waterton/St. Mary Res RESERVOIR ELEVATION SUMMARY No. 2



- ▩ E3 – Maximum
- ▨ Upr RC – E3
- ■ E2 – Upr RC
- ▒ Lwr RC – E2
- ■ E1 – Lwr RC
- ■ Minimum – E1

2001 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

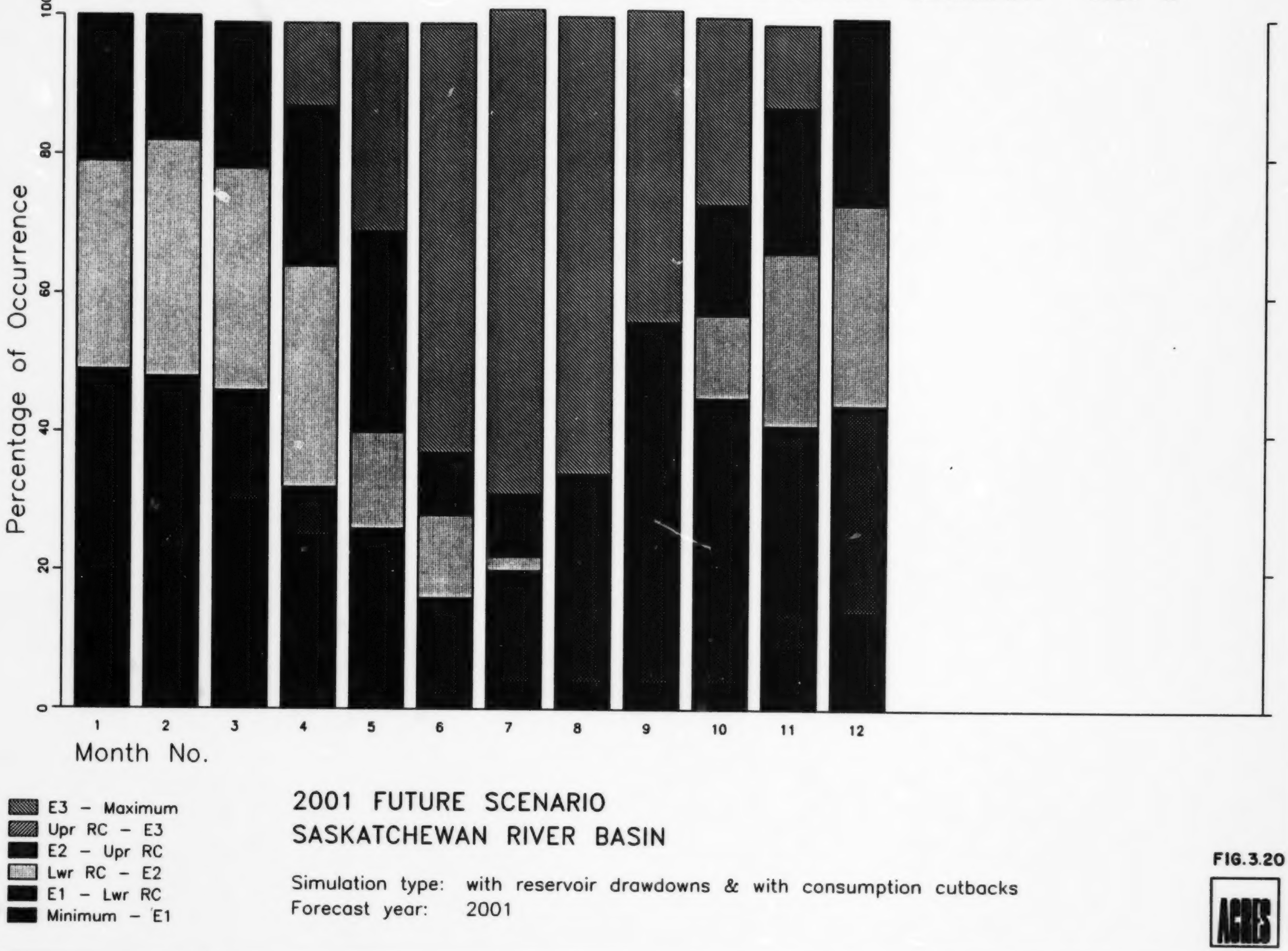
Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2001

FIG.3.19

AGRES

Dickson Reservoir

RESERVOIR ELEVATION SUMMARY No. 3



2001 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

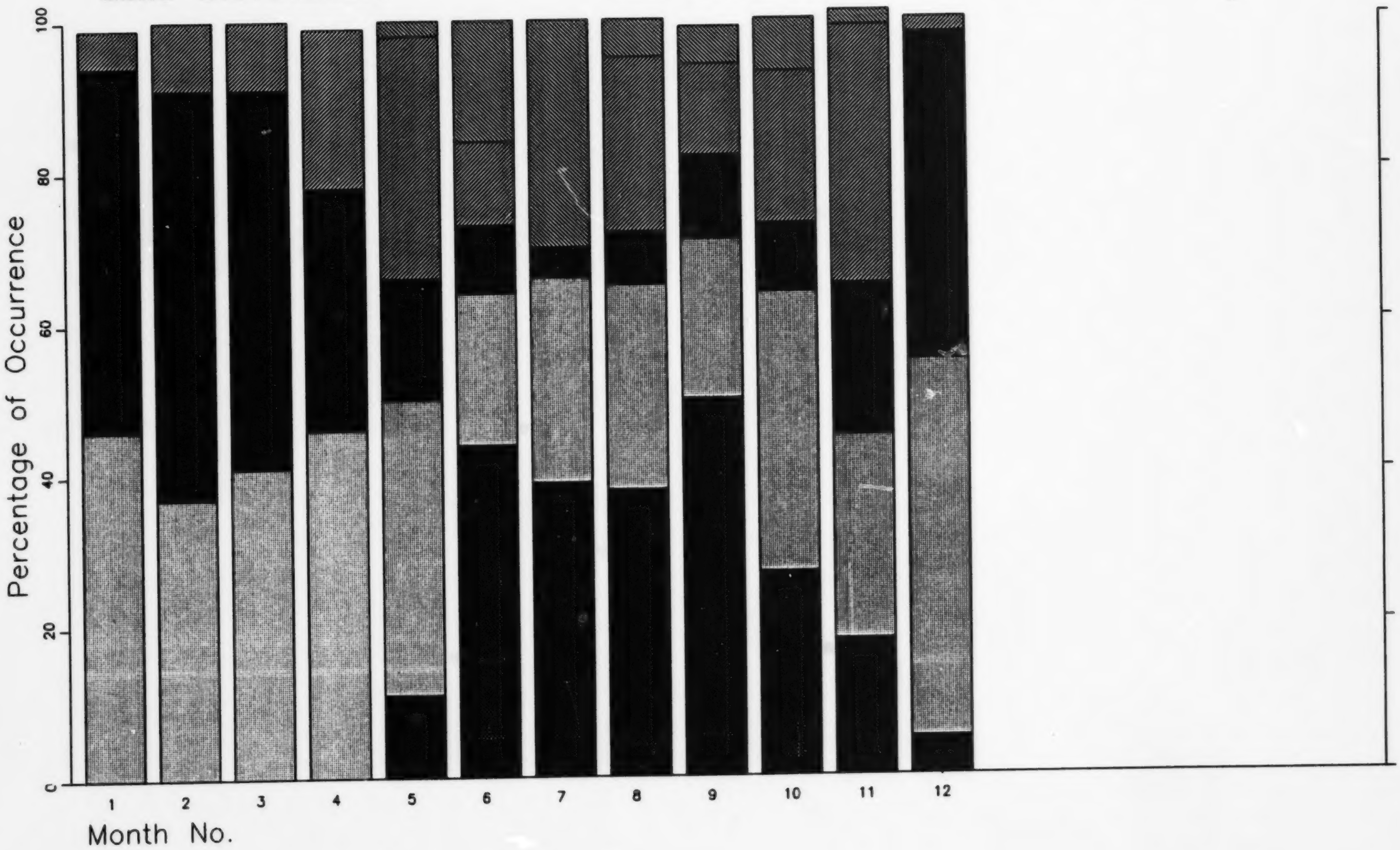
Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2001

FIG.3.20

ACRES

Lake Diefenbaker

RESERVOIR ELEVATION SUMMARY No. 4



2001 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2001

FIG.3.21

ACRES

TABLE 3.20

CONSUMPTION CUTBACKS SUMMARY, BATTLE RIVER BASIN
FUTURE SCENARIO, 2001

		Consumption Cutbacks Summary	Percentage of Occurrences		
Month	**No.**	**Domestic**	**Livestock**	**Industrial**	**Irrigation**
Jan	56	0.0	0.0	0.0	0.0
Feb	56	0.0	0.0	0.0	0.0
Mar	56	0.0	0.0	0.0	0.0
Apr	56	0.0	0.0	0.0	0.0
May	56	0.0	0.0	0.0	0.0
June	56	8.9	14.3	16.1	14.3
July	56	28.6	30.4	32.1	30.4
Aug	56	26.8	30.4	30.4	28.6
Sept	56	37.5	42.9	42.9	42.9
Oct	56	0.0	0.0	0.0	0.0
Nov	56	0.0	0.0	0.0	0.0
Dec	56	0.0	0.0	0.0	0.0
Season	280	20.4	23.6	24.3	23.2
Annual	672	8.5	9.8	10.1	9.7

		Consumption Cutbacks Summary	Min/Avg/Max Cutbacks (%)		
Month	**No.**	**Domestic**	**Livestock**	**Industrial**	**Irrigation**
Jan	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Feb	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Mar	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Apr	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
May	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
June	56	8.5 / 8.5 / 8.5	10.0 / 10.0 / 10.0	6.9 / 25.8 / 48.8	5.2 / 22.5 / 40.0
July	56	8.5 / 8.5 / 8.5	7.3 / 9.8 / 10.0	3.9 / 31.8 / 46.6	0.2 / 28.8 / 40.0
Aug	56	6.0 / 8.2 / 8.5	4.8 / 9.7 / 10.0	10.0 / 21.2 / 40.0	4.8 / 18.9 / 38.9
Sept	56	8.5 / 8.5 / 8.5	10.0 / 10.0 / 10.0	5.0 / 26.0 / 40.0	1.0 / 21.5 / 35.0
Oct	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Nov	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Dec	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0

(c) 2011 Future Scenario

- The further increase in consumption demands at the principal irrigation supply nodes in the 2011 scenario leads to corresponding supply deficits being indicated as follows.

Subbasin Node		Frequency of Occurrence (%)			
		All Deficits		Large Deficits	
Name	No.	Monthly	Seasonal	Monthly	Seasonal
Waterton/ St. Mary	2	25	71	24	57
Lethbridge	3	2	0	0	0
Bassano	5	17	29	13	9
Diefenbaker	17	6	0	5	0

The deterioration of supply reliability from 2001 to 2011 for the Waterton/St. Mary subbasin (Node 2) is not large; however, the supply reliability clearly exceeds the 20% criterion selected.

The absence of large seasonal deficits indicated for the Lethbridge subbasin (Node 3) is again due to the regulating effect of the Oldman reservoir. Deficits for the Bassano subbasin (Node 5) are shown to increase further in frequency, but not to an unsatisfactory level. A few monthly deficits are shown to occur at Lake Diefenbaker (Node 17) in this scenario, but essentially there are no availability problems indicated, in spite of the large increases in irrigation and diversion demands at this location. Note that while availability problems may not exist at a reservoir, water level problems can occur due to the inability of the reservoir to satisfy the instream use requirements reflected in the lower rule curve levels.

- There are no major changes to the water availability situation at other locations in the Saskatchewan River basin. At most of the locations where deficits were identified previously, small increases in frequency of occurrence of deficits are indicated.

- Simulated hydroelectric energy generation for this scenario is summarized in Table 3.21. Generation at all the downstream plants is lower than for the 2011 scenario, due to the consumption demand increases.

- Lower rule curve violations as simulated at the four reservoirs explicitly modeled in the 2011 scenario are shown below.

	Frequency of Occurrence of Monthly Lower Rule Curve Violations (%)*			
Reservoir	**In Year**	**In Season**	**June**	**July**
Waterton/ St. Mary	17	15	12	0
Oldman	0	0	0	0
Dickson	38	30	16	20
Diefenbaker	24	42	46	46

The Oldman reservoir is shown to continue to operate without any lower rule curve violations in this 2011 scenario, and there is no change from the 2001 scenario indicated in the performance of the Dickson reservoir. Indicated frequencies of occurrence of monthly lower rule curve violations at Lake Diefenbaker increase to 24% over the year and 42% over the irrigation season. At the

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*Calculated as the number of months with simulated violations divided by the number of simulation months, expressed as a percentage.

TABLE 3.21

SIMULATED AVERAGE HYDROELECTRIC ENERGY GENERATION
FUTURE SCENARIO, 2011

Plant Name	Node No.	Average Energy Generation (GW·h) Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Kananaskis	4	5.8	5.1	5.6	7.2	8.7	12.5	12.7	11.2	8.4	6.8	5.7	5.7	85.4
Horseshoe	4	5.2	4.6	5.0	6.4	7.2	9.3	9.6	9.3	7.2	6.0	5.0	5.1	79.9
Ghost	4	10.7	9.5	10.4	13.3	16.4	28.7	28.4	21.7	15.6	12.5	10.5	10.6	188.3
Barrier	4	2.6	2.3	2.5	3.2	4.0	7.0	6.9	5.3	3.8	3.0	2.6	2.6	45.8
Cascade	4	3.1	2.7	3.0	3.8	4.7	9.0	8.8	6.2	4.5	3.6	3.0	3.0	55.4
Spray	4	13.0	11.5	12.6	16.1	20.0	38.1	37.1	26.4	19.0	15.2	12.8	12.8	234.6
Three Sisters	4	0.3	0.3	0.3	0.4	0.4	0.9	0.8	0.6	0.4	0.3	0.3	0.3	5.3
Rundle	4	4.5	4.0	4.3	5.5	6.9	13.1	12.7	9.0	6.5	5.2	4.4	4.4	80.5
Bearspaw	4	4.5	3.9	4.3	5.5	6.8	10.4	10.6	8.8	6.5	5.2	4.4	4.4	75.3
Interlakes	4	0.5	0.5	0.5	0.6	0.8	1.5	1.5	1.0	0.8	0.6	0.5	0.5	9.3
Pocaterra	4	1.7	1.5	1.7	2.1	2.6	5.0	4.9	3.5	2.5	2.0	1.7	1.7	30.9
Big Bend	24	28.3	25.6	27.8	26.8	29.7	47.5	74.0	61.2	41.9	30.9	27.4	28.3	449.4
Big Horn	23	21.6	19.4	21.3	20.3	21.5	24.8	51.0	57.3	34.7	22.5	20.9	21.6	336.9
Coteau Creek	17	98.3	87.6	74.6	52.5	55.3	55.8	52.0	39.7	33.2	44.7	63.5	76.4	733.6
Squaw Rapids	29	77.9	67.7	62.2	97.8	127.2	94.7	146.6	147.2	108.9	89.1	83.0	72.3	1174.6
Nipawin	29	71.1	61.7	56.7	89.2	115.3	86.1	132.4	132.7	98.8	80.9	75.6	65.9	1066.4
TOTAL		349.1	307.9	292.8	350.7	427.5	444.4	590.0	531.1	392.7	328.5	321.3	315.6	4651.6

Waterton/St. Mary reservoir, lower rule curve violations remain at 17%.

Figures 3.22, 3.23, 3.24 and 3.25 show the elevation summary plots for the four reservoirs.

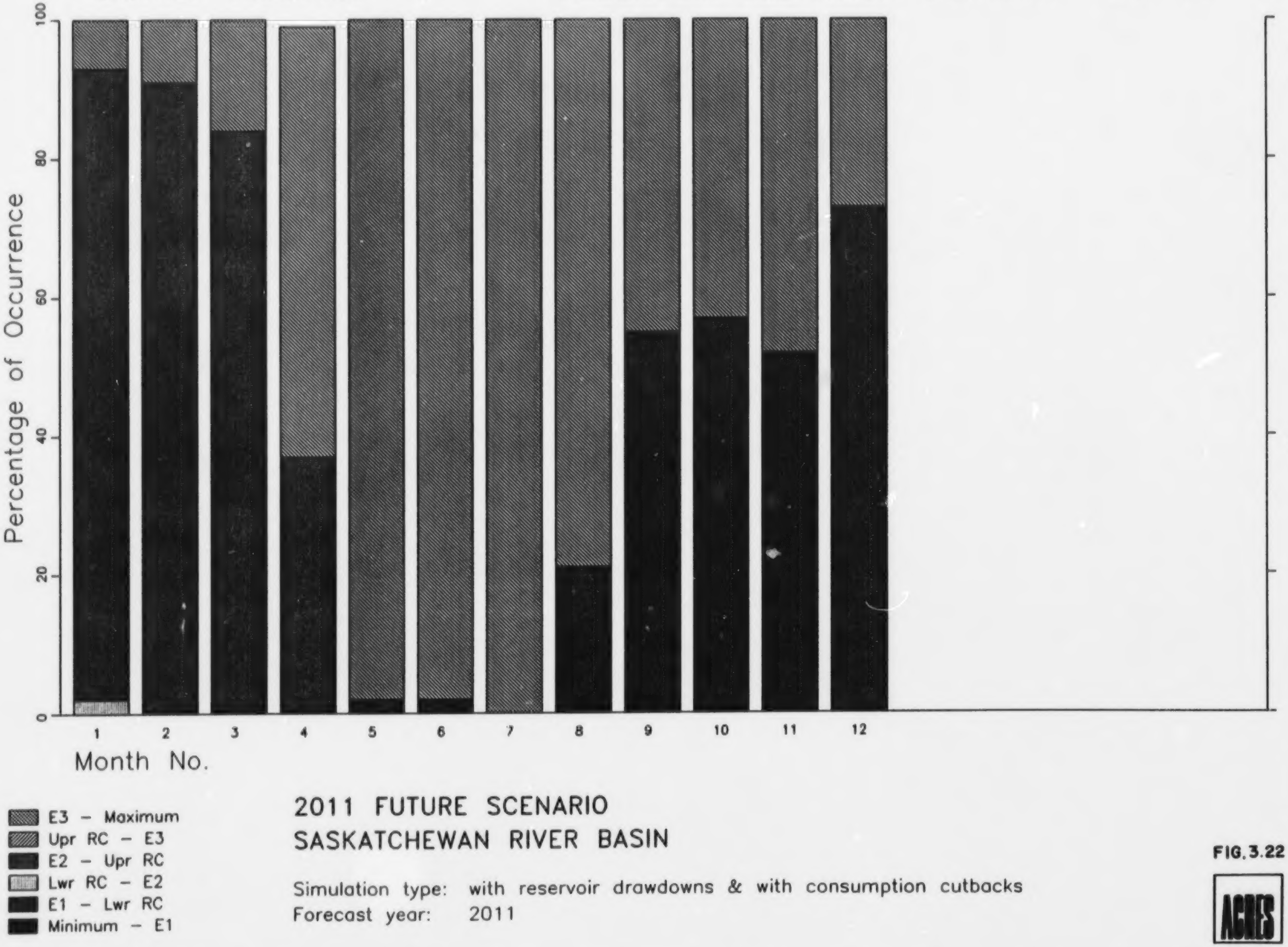
- As in the previous scenarios, only the Battle River (Node 21) is shown to produce provincial boundary flow shortages and to require water use cutbacks. Monthly shortages occur 10% of the time overall or 24% of the time during the irrigation season, with no shortages outside of the season. Required monthly water use cutbacks in times of shortage average 24% of demand. Table 3.22 shows the corresponding cutback distributions by time and category.

(d) Critical Supply Availability

- Supply availability in the Waterton/St. Mary subbasin (Node 2) is shown to deteriorate from satisfactory levels in the 1982 case to seriously critical and unacceptable levels in the 2001 and 2011 scenarios. A perspective of the average monthly supply and demand situation for each of the scenarios is given in Figures 3.26, 3.27 and 3.28 respectively. These figures, which were produced by the model, show the peak demand lagging the peak supply by one month, and that a notable reduction in deficits in July, August and September would result if this lag were not present. The regulation of the reservoir does reduce the supply deficits from the levels simulated in Phase VI when the reservoir was not modeled.

- In the Berry Creek subbasin (Node 13), a near-critical supply situation is shown to exist in the 1982 case. Subsequent implementation of irrigation area development is coupled with a thermal power plant development and two

Oldman Reservoir RESERVOIR ELEVATION SUMMARY No. 13



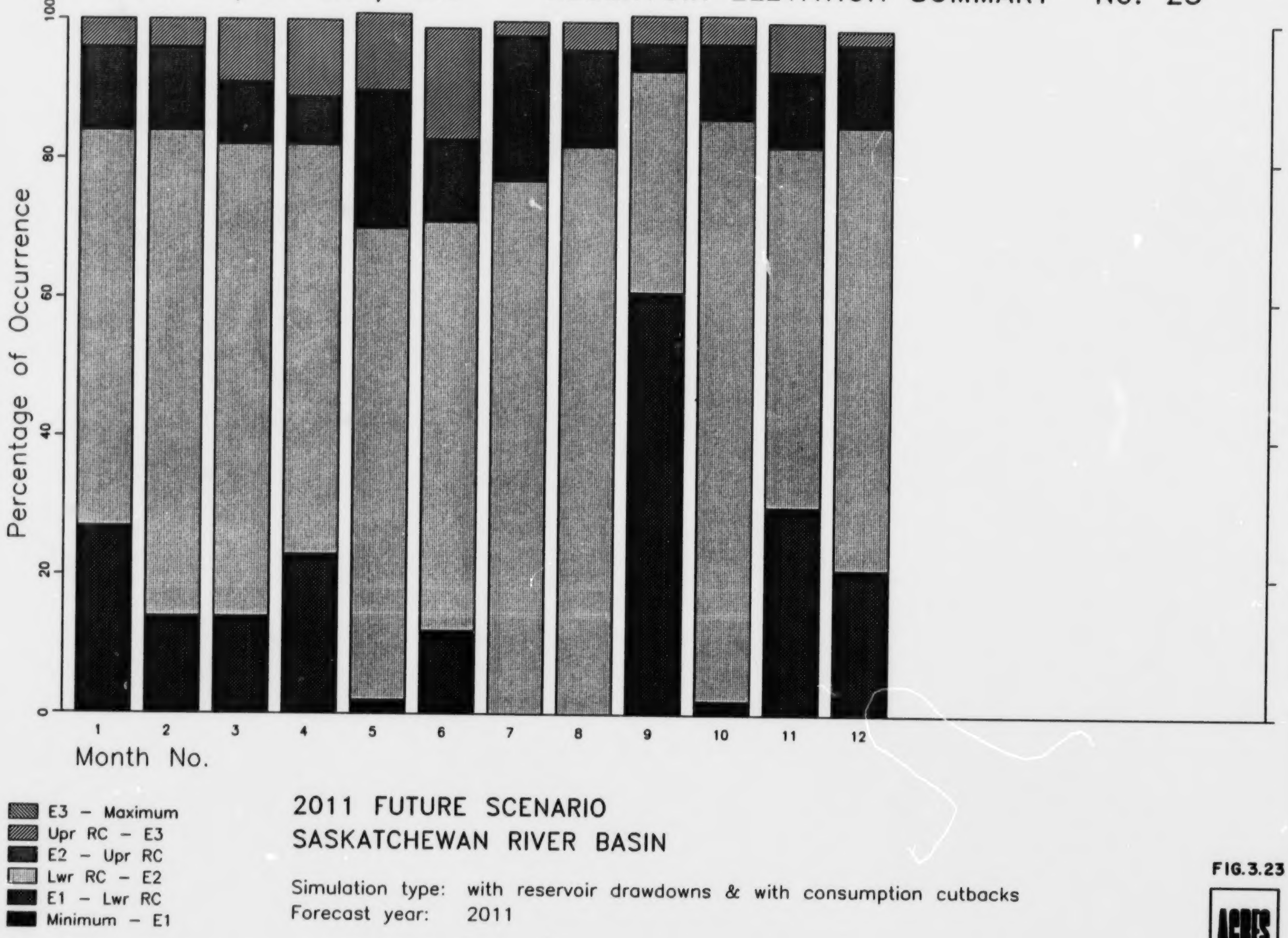
2011 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2011

FIG. 3.22

ACRES

Waterton/St. Mary Res RESERVOIR ELEVATION SUMMARY No. 23



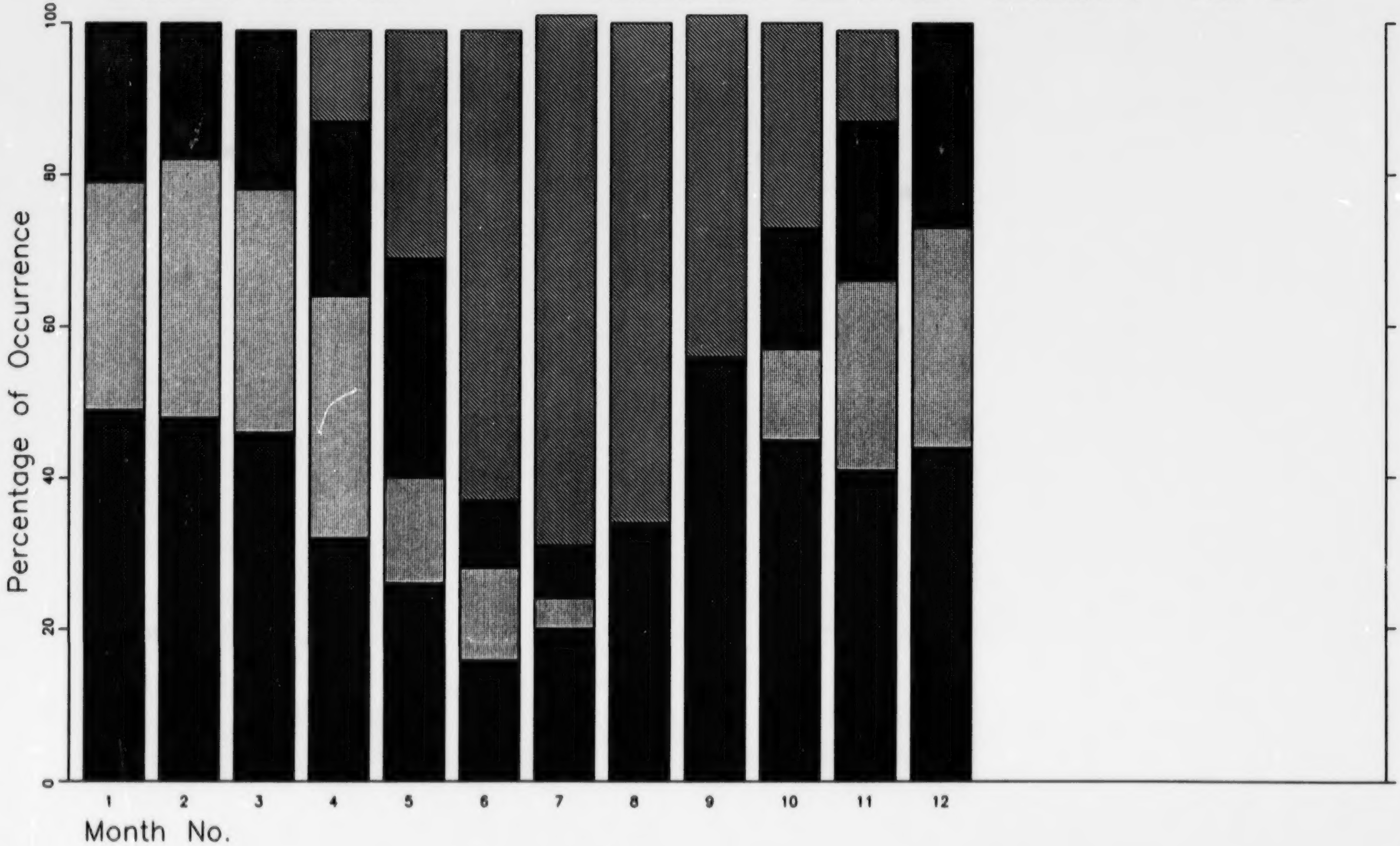
2011 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2011

FIG.3.23

ACRES

Dickson Reservoir RESERVOIR ELEVATION SUMMARY No. 33

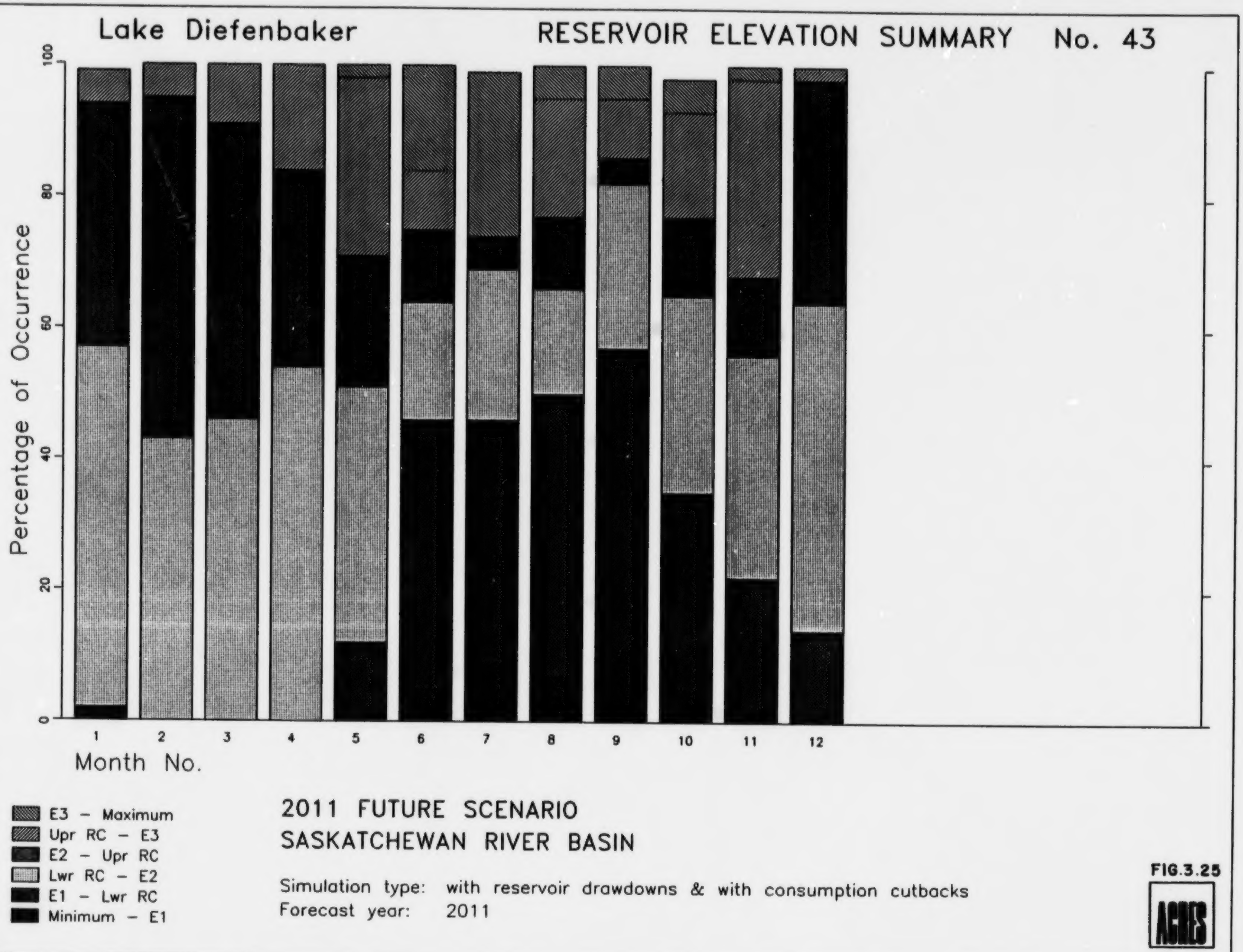


2011 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2011

FIG.3.24

ACRES



Lake Diefenbaker

RESERVOIR ELEVATION SUMMARY No. 43

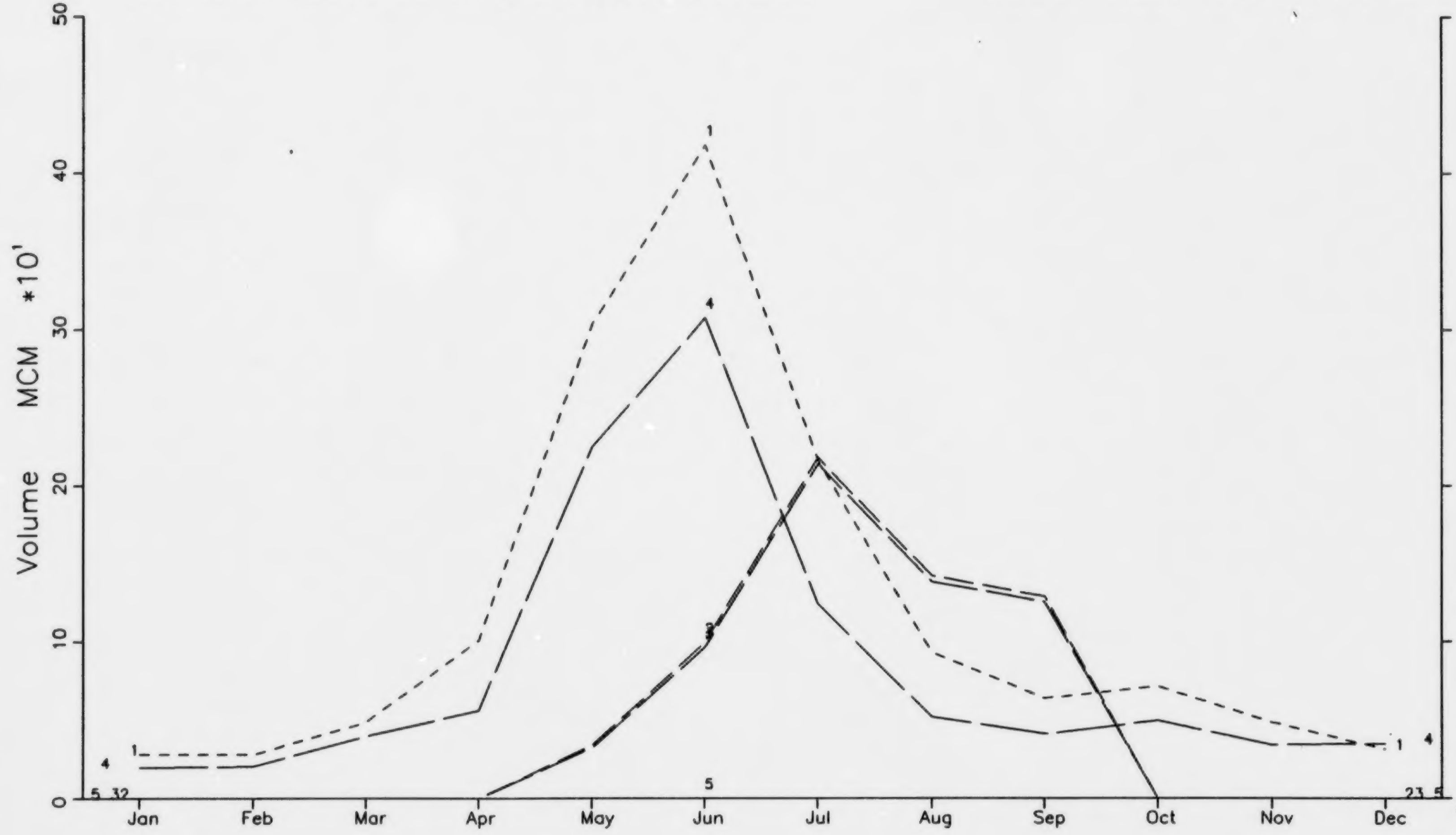
2011 FUTURE SCENARIO

SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2011

FIG.3.25

MONTHLY SUPPLY & DEMAND VOLUMES Node: WSM RES No. 2



1982 BASE CASE
SASKATCHEWAN RIVER BASIN

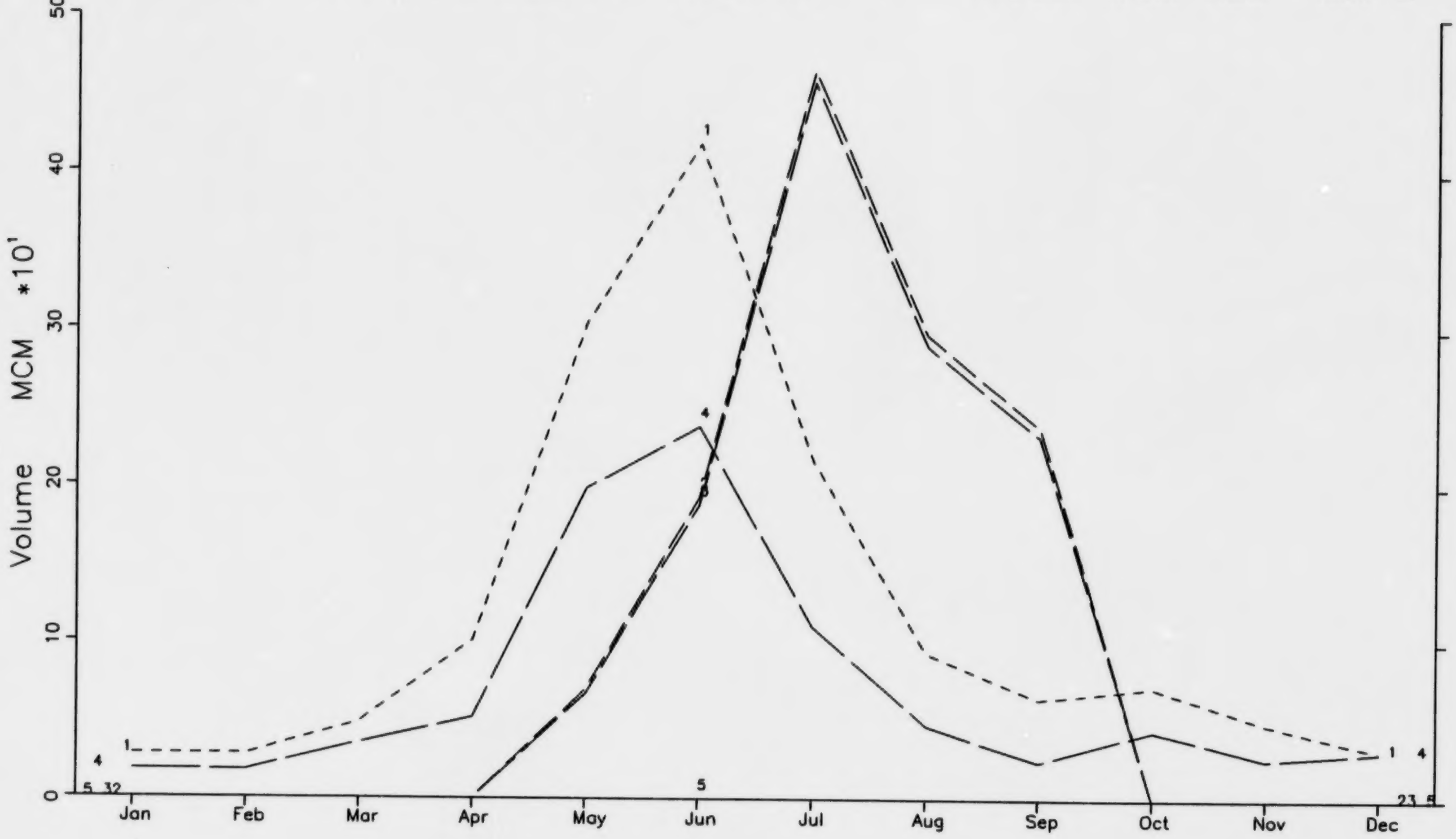
Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG. 3.26

ACRES

MONTHLY SUPPLY & DEMAND VOLUMES

Node: WSM RES No. 2



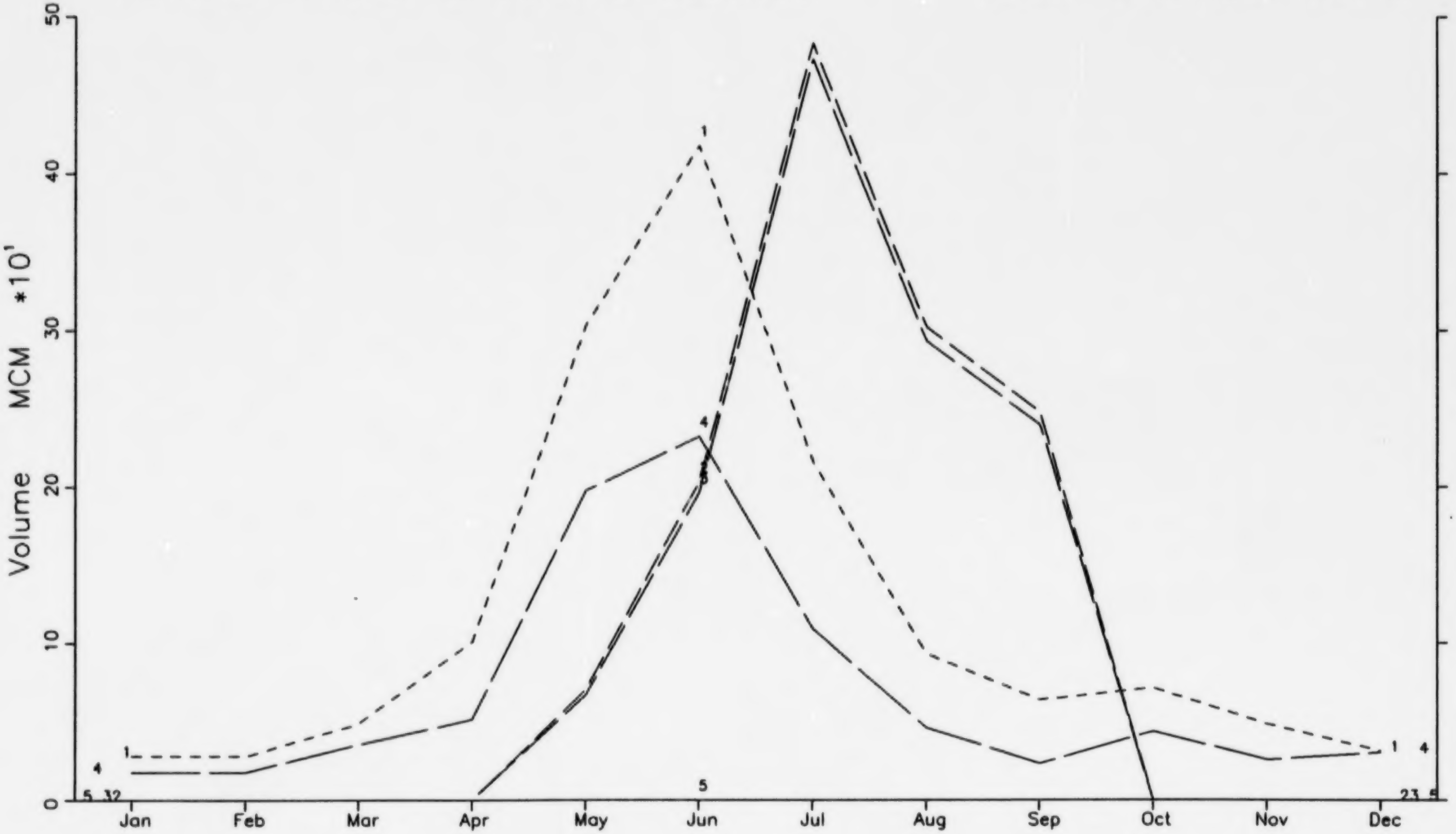
2001 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2001

FIG.3.27

ACRES

MONTHLY SUPPLY & DEMAND VOLUMES Node: WSM RES No. 2



2011 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2011

FIG.3.28

ACRES

TABLE 3.22

CONSUMPTION CUTBACKS SUMMARY, BATTLE RIVER BASIN
FUTURE SCENARIO, 2011

		Consumption Cutbacks Summary		Percentage of Occurrences	
Month	**No.**	**Domestic**	**Livestock**	**Industrial**	**Irrigation**
Jan	56	0.0	0.0	0.0	0.0
Feb	56	0.0	0.0	0.0	0.0
Mar	56	0.0	0.0	0.0	0.0
Apr	56	0.0	0.0	0.0	0.0
May	56	0.0	1.8	1.8	1.8
June	56	10.7	17.9	10.7	16.1
July	56	25.0	37.5	32.1	37.5
Aug	56	25.0	28.6	28.6	28.6
Sept	56	39.3	46.4	48.2	44.6
Oct	56	0.0	0.0	0.0	0.0
Nov	56	0.0	0.0	0.0	0.0
Dec	56	0.0	0.0	0.0	0.0
Season	280	20.0	26.4	24.3	25.7
Annual	672	8.3	11.0	10.1	10.7

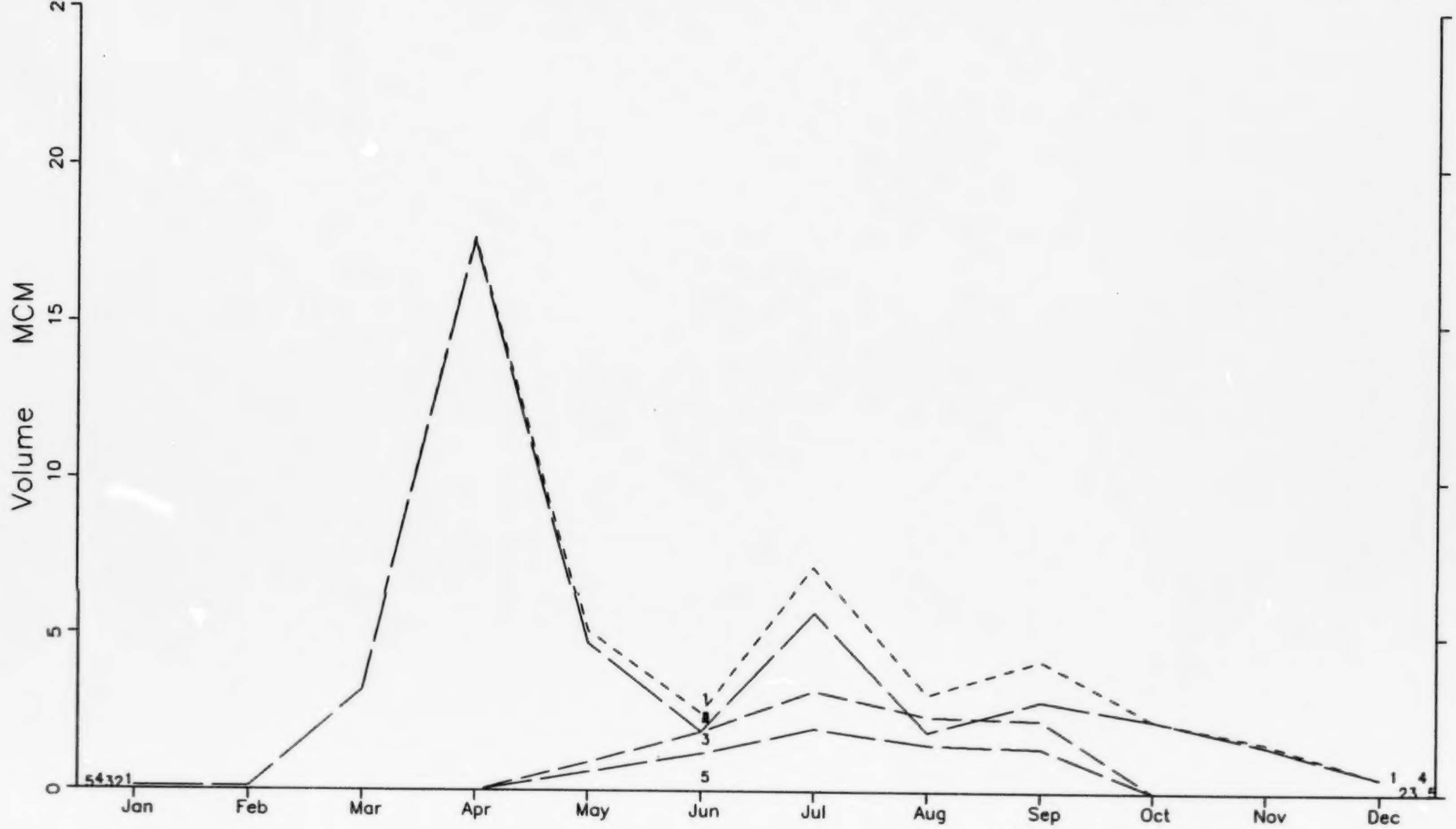
		Consumption Cutbacks Summary		Min/Avg/Max Cutbacks (%)	
Month	**No.**	**Domestic**	**Livestock**	**Industrial**	**Irrigation**
Jan	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Feb	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Mar	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Apr	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
May	56	0.0 / 0.0 / 0.0	10.0 / 10.0 / 10.0	10.0 / 10.0 / 10.0	8.6 / 8.6 / 8.6
June	56	8.5 / 8.5 / 8.5	8.8 / 9.9 / 10.0	18.7 / 27.5 / 40.0	2.0 / 16.2 / 39.8
July	56	8.5 / 8.5 / 8.5	10.0 / 10.0 / 10.0	10.0 / 25.1 / 50.0	0.7 / 19.6 / 43.0
Aug	56	4.9 / 8.2 / 8.5	10.0 / 10.0 / 10.0	1.9 / 26.4 / 40.0	5.3 / 23.0 / 37.4
Sept	56	8.5 / 8.5 / 8.5	2.9 / 9.7 / 10.0	9.2 / 24.3 / 40.0	5.3 / 22.0 / 39.3
Oct	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Nov	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0
Dec	56	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0	0.0 / 0.0 / 0.0

diversions from the Red Deer River. An adjustment to the assumed diversion into the basin in this phase results in an increase in supply deficits in 2001 and 2011. A perspective of this development program and its impact on supply availability is provided by the plots of average monthly supply and demand for the three scenarios, shown in Figures 3.29, 3.30 and 3.31 respectively.

- While supply availability is generally satisfied at Lake Diefenbaker, there are frequent violations of the lower rule curve. This implies the reservoir levels established based on instream water use requirements cannot be reliably maintained.

MONTHLY SUPPLY & DEMAND VOLUMES

Node: 05CH007 No. 13



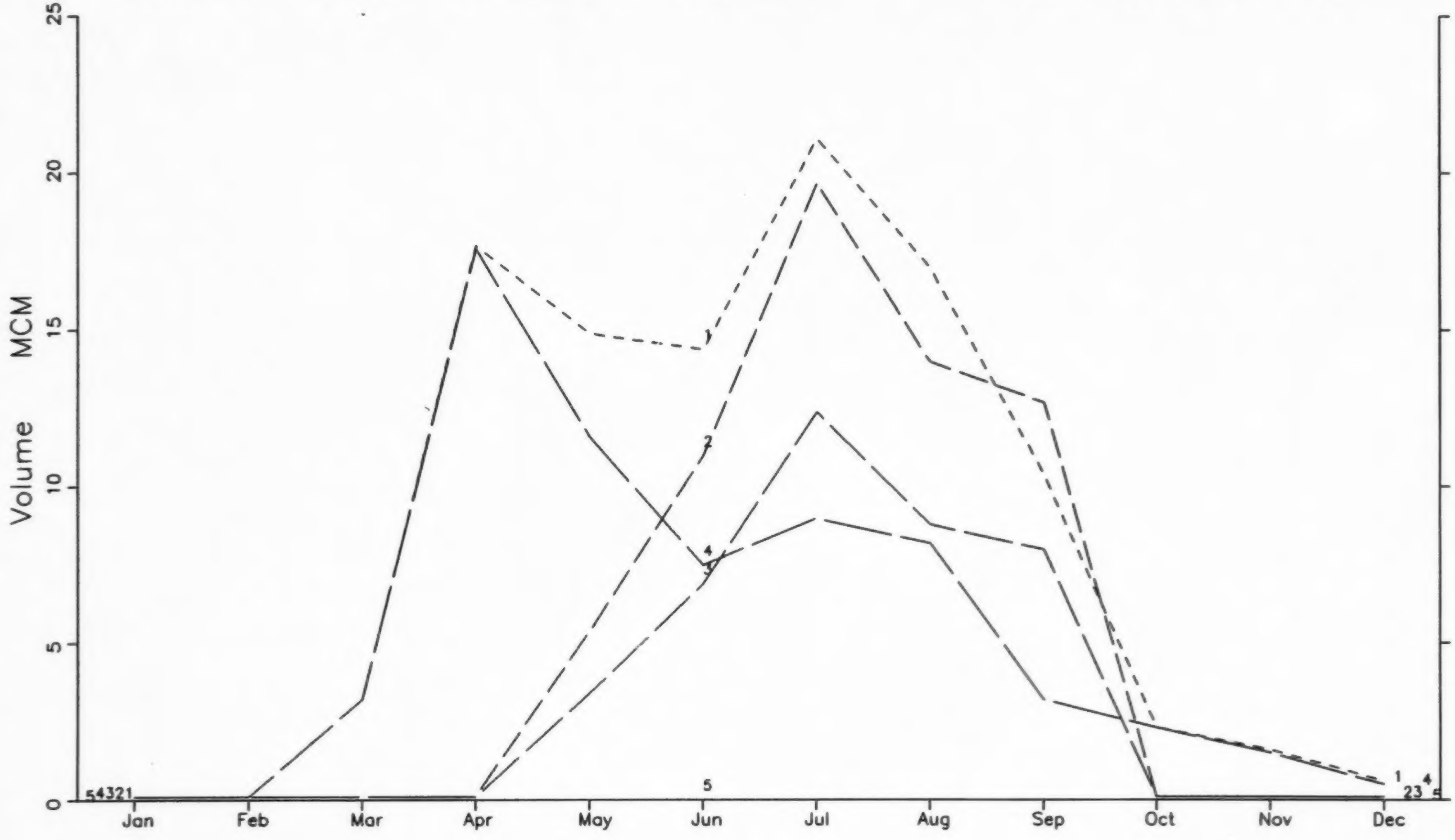
1982 BASE CASE
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 1982

FIG.3.29

ACRES

MONTHLY SUPPLY & DEMAND VOLUMES Node: 05CH007 No. 13



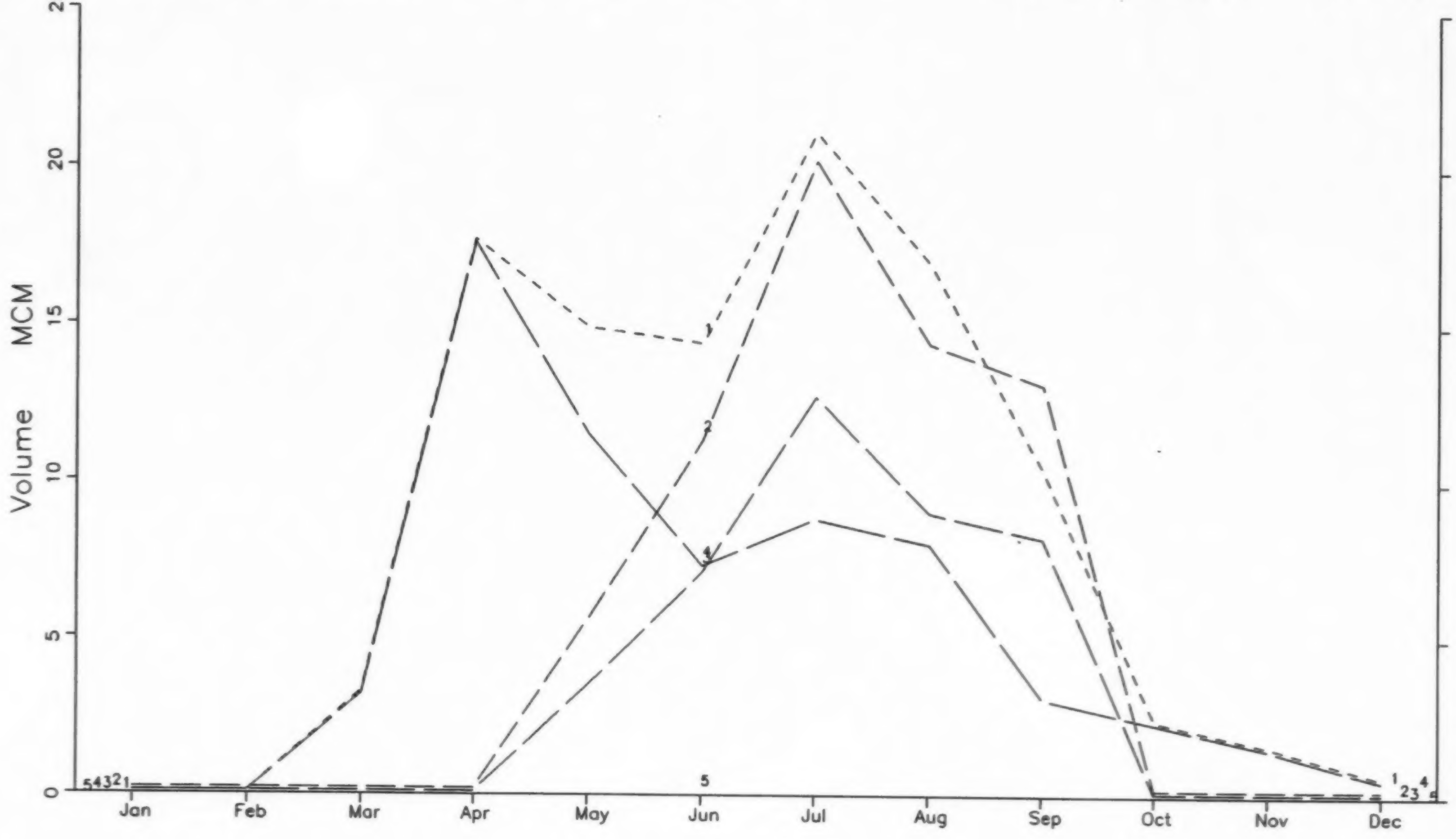
2001 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2001

FIG.3.30

AGRES

MONTHLY SUPPLY & DEMAND VOLUMES Node: 05CH007 No. 13



2011 FUTURE SCENARIO
SASKATCHEWAN RIVER BASIN

Simulation type: with reservoir drawdowns & with consumption cutbacks
Forecast year: 2011

FIG.3.31

ACRES

4 - SUMMARY AND CONCLUSIONS

4 - SUMMARY AND CONCLUSIONS

Work undertaken in Phase VII includes model improvements and scenario evaluations. A summary and conclusions for each of these areas is given in this section.

4.1 - Model and Data Base Improvements

(a) Data Processing

The model now allows for the use of monthly evapotranspiration data over the period of record in the same fashion as precipitation data is utilized.

The model and data base have been modified to utilize streamflow data prepared in metric units. All available streamflow data files were converted to metric units for use in the model.

A utility module has been added to prepare nodal output files for use as input data in subsequent subnetwork analyses.

All data files allow the user to append identification lines to the end of the file to assist in the documentation of files used in the model.

(b) Industrial Water Use Analysis

The model has been modified to replace the previous regionally based, industrial growth forecasts by provincial industrial growth forecasts prepared by Informetrica Limited. The model now operates using regions which can be the same as provinces.

The interregional inverse matrices are no longer used by the model to express sectoral linkages between regions. The intraregional matrices, which express impacts between sectors within a given economic region (province), have been changed for the new provincial economic regions. Other data base adjustments required to complete the conversion to provincial economic regions were also completed.

(c) Industrial Water Demand/Price Analysis

The model now allows a user to select one of three methods of evaluating the effect of water price increases on the intake demand.

- the price curves method
- the price coefficients method
- the price elasticity method

The price curves method is the original routine added in a previous phase. The latter two methods are based on recent research results which developed regression equations, for manufacturing industries relating water demand to its price.

(d) Reservoirs

Data required for the explicit modeling of the Waterton/St. Mary reservoir in southern Alberta was obtained or derived and incorporated into the data base. The reservoirs are operated in tandem to regulate natural streamflows for use in several of the major irrigation districts of the province. This operation has been simulated in the model by developing a single composite reservoir which is added to the network.

(e) Data Base Expansions

The data base for the Saskatchewan River basin was extended to allow for the evaluation of scenarios in the year 2011. Expansion of the data base has included industrial, irrigation, energy projects and other components of the forecast development in the basin at the scenario year.

Data on steam-thermal and hydroelectric power plants was reviewed with the principal utilities in Alberta and Saskatchewan to develop an appropriate generation scenario for the years 2001 and 2011.

Recent information on irrigation development in the Saskatchewan River basin in Alberta and Saskatchewan was applied to update previous estimates of future irrigated areas and diversions.

Urban and rural population forecasts were changed to values given in recent Statistics Canada forecasts.

Projections for special new energy projects were reviewed to produce updated forecasts of projects in place in 2001 and 2011.

4.2 - Scenario Data

Scenario evaluations were carried out for the Saskatchewan River basin in Alberta and Saskatchewan. The scenarios included a 1982 base case and future scenarios for 2001 and 2011. The principal results of the scenario evaluations are similar to those found in Phase VI and are described below.

- Availability of supply for the large irrigation areas dependent on the Waterton/St. Mary/Belly subbasin was satisfactory in 1982 but will be unacceptable by 2001 based on the estimated levels of development. The situation does not deteriorate significantly between 2001 and 2011 because of the slower rate of irrigation development.

- Availability of supply for estimated irrigation and other water uses dependent on the Oldman River is assured with the Oldman reservoir in service. An acceptable water availability situation will also exist up to 2011 for the large irrigation and other consumption demands on the Bow River. There are no availability problems indicated elsewhere on the main stem system including Lake Diefenbaker from the scenarios modeled. However, at Lake Diefenbaker there will be frequent lower rule curve violations, indicating that instream water use requirements based on reservoir levels will not be satisfied reliably.

- Supply availability is shown to be a serious problem in the Battle River basin and in the small subbasins that are modeled separately. These basins have very low flows, and the results of the evaluations may be highly sensitive to small changes in the water use and supply assumptions.

5 - RECOMMENDATIONS

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The WUAM has now been developed to the stage where it can be applied with confidence to the assessment of many water resource issues. Representation of most of the demand (irrigation, livestock, industrial, etc) and supply (natural runoff, reservoir regulation and diversions) is at a stage where further improvements are not warranted. Similarly, the interface between the user and the machine is at an advanced stage of development.

There are a few areas where further enhancements of the model would be advantageous. These are listed below.

5.1 - Model Improvements

(a) Groundwater Modeling

Groundwater supplies have been included in the WUAM as a fraction of the demanded intake in the various water use sectors. The values are provided in the gauge detail and irrigation area files as monthly data. The volume to be extracted in a given month is calculated but limited to a specified maximum. In the event of a consumption cutback to meet apportionment requirements, the groundwater supply is not reduced.

A desirable improvement to groundwater modeling is the simulation of specific aquifers and their limitations, maximum withdrawal and recharge rates. Aquifers would be simulated in a manner similar to that used for reservoirs. In the event of a consumption cutback, the groundwater supply could be increased to partially compensate for the reduction in surface water supply.

The model would attempt to achieve a monthly continuity between moisture stored in the aquifer, evapotranspiration from the upper zones, withdrawals from the aquifer and recharge. In some cases the model would allow the aquifer to be mined with a long-term reduction in storage.

The first stage in the improvement of the groundwater modeling features in WUAM should be a review of other available models and the theoretical basis for development of an appropriate algorithm. Data sources such as federal and provincial governments would be evaluated and relevant information selected.

Improvement of groundwater modeling will enhance the capability of the WUAM to study basins with significant part of total water supply derived from groundwater and allow groundwater supply to interact better with surface water supply. A more detailed accounting of groundwater will be of particular value if the model is used for assessing the impacts of climatic change. Groundwater sources may begin to play a very important role as water use practices adjust to changing climatic conditions.

(b) Water Quality Model

A major extension of the capabilities of the WUAM would be the inclusion of algorithms to relate the quality of the available water supply to causative factors. The model would examine the expected effluent loadings from various sources to determine the quality of water at downstream locations.

The model currently uses a monthly time step in the simulation of the basin network. However, many constituents of water quality are non-conservative and therefore, a time dependent decay must be simulated. A water quality submodel could operate as a post-processor, taking the results of the historical simulation of water quantity in the network from MODULE 8 to perform analyses using appropriate time steps.

The first stage of this study would be the identification of which pollutants should be simulated by the model and appropriate simulation techniques. An algorithm would then be developed to estimate water quality based on the data available to model users.

(c) Apportionment

As presently simulated by the model, a flow shortage at a jurisdictional boundary is identified and acted upon if both of the following conditions apply

- modeled outflow (based on available supply) is less than required outflow (based on division of natural flows)

- modeled consumption is greater than permitted consumption.

If only the first of these applies, the flow deficit is assumed to be held in 'beneficial' storage for future release as appropriate, and no corrective action is taken, either in the form of additional reservoir releases or water rationing. As long as consumption does not exceed the permitted consumption, the portion of flow not passed across the boundary must be held in storage somewhere in the system. The model assumes that the required annual volume will be discharged although the timing will be different from the natural flow. The current version of the model has no provision for simulating releases from 'beneficial' storage.

The total apportionment volume requirement is to be met over the period of 1 year, but there is also a requirement for 'equitable' apportionment over time. The current version of the model effectively defines this as a requirement to meet apportionment commitments on a monthly basis. This is a conservative approach, but if it is to be followed strictly, then a logical model change would be to arrange for releases from 'beneficial' storage to be made in the same month as the corresponding flow shortage. In terms of the present model and data base setup, this modification to the apportionment routine would best be implemented once all the important reservoirs have been explicitly incorporated into the data base.

(d) Minimum Flows

To assist with the specification of minimum flows at nodes of the network, other than at reservoirs or for apportionment, a differentiation between categories would be desirable. As was found in Phase IV, different categories (e.g., sanitary, fishery, recreational) have different minimum flow requirements and distributions through the year. These need to be assembled and an envelope of 'maximum values of minimum flows' produced for model applications. It would be quite advantageous to allow the model to undertake this, as well as to institute a check for reasonable minimum flow values compared to the natural flows.

(e) Electric Energy Water Use

As discussed in Phase VI, further development of the EEWUS should concentrate on incorporation of energy stacking to allow for a link between hydroelectric and thermal electric generation. We would presently favor a simplified approach to stacking in preference to a fully integrated stacking procedure.

This model enhancement would need to be implemented in conjunction with a system-wide rather than a basin-wide definition of power plants and their contribution to electrical load.

(f) Irrigation Water Use

There is one area in the Irrigation Water Use Submodel (IWUS) where a concept modification may be desirable. This relates to modeling of irrigation level. The application of a factor representing 'level of irrigation', to obtain 'actual' from 'optimal' monthly irrigation, is undertaken using theoretical values of 'optimal' monthly irrigation. In the present version of the model, these values are estimated from modeled start-of-month soil moisture depletions, and are therefore dependent on assumed actual irrigation practices in previous months. This interpretation of optimal irrigation results in a lack of sensitivity in model responses to changes in the irrigation level, when viewed on a seasonal basis. An alternative and preferable interpretation from this viewpoint would treat optimal irrigation on a seasonal basis. Monthly optimal irrigation calculations would assume optimal irrigation practice in the previous months also, thus rendering them independent of assumed actual irrigation previously in the season.

If the submodel is changed as suggested above, then its application to evaluations with the current data base and network will require a comprehensive program of calibration runs covering all the irrigation areas for which 1982 data are available. The revised method of calculation should result in somewhat higher, probably more realistic, seasonal values of irrigation level than those included for the base year in the present data base. This should then provide greater confidence in the selection of alternative future values for scenario evaluations.

(g) Graphics

In conjunction with the model enhancement relating to minimum flows, discussed in Section 5.1(b), the demand bar chart showing minimum flow requirements should be modified to show the dominant minimum flow category at each node of the network.

If it is envisaged that the EEWUS and IWUS will find applications and will be used independently of the WUAM, then it may be appropriate to develop additional graphics for these submodels.

(h) Node Numbering

The use of the model would be facilitated if internal node numbers were selected by the model independently of external identification numbers selected by the user. This would allow the user to assign an unrelated node number to each gauge. In this way the same node could be referenced in more than one network and nodes could be added to a network without renumbering.

(i) Multiple Basin Analyses

The name of the basin data files should be variable rather than fixed as a BASIN.DAT and BASIN.HYD. This would allow the user to maintain several different data files without renaming files to run the model. This improvement could result in a re-arrangement of the DATA subdirectory.

(j) Output Format

Several model users have commented that when analyzing basins, including several small subbasins, the format currently used for the output of reports does not provide a sufficient number of decimal places. The model should be adjusted so that print formats for small basin analyses yield sufficient information for the user.

(k) Batch Mode

Users of the model have commented that a capability to perform batch mode runs would be a desirable program enhancement. This would allow the user to prepare data files and run several scenarios without having to be on hand to provide interactive input. A user could then conveniently run the model unattended in evening hours to make better use of computer time.

5.2 - Data Base Improvements

(a) Electric Energy

Data on hydro and thermal electric energy generation and water use have been prepared only for the Saskatchewan River basin in Alberta and Saskatchewan. For reasons of completeness and compatibility with previous phases, this should be extended to cover the entire Saskatchewan-Nelson basin within the prairie provinces. In addition, if the EEWUS is to be developed further, as suggested in Section 5.1(c), then the research and data base should be extended to cover the full prairie provinces region so as to represent the provinces' complete electric systems.

(b) Streamflows

The present version of the natural streamflow data base covers the period 1912 to 1967. It is known that extended data have been prepared for at least a part of the modeled basin and that there have been important subsequent low flow years. Depending on the availability of such data, the streamflow data base could usefully be reassembled, not necessarily to cover the entire period of record, but to form a record for a suitably representative period of years.

(c) Closed Drainage Basins

Some queries have arisen in previous phases and scenario evaluations concerning the designation of closed drainage basins and their treatment in the model data base. It needs to be recognized that water use and availability in the closed basins cannot be usefully modeled by the WUAM in the context of the prepared streamflow network, except for water supply diverted from the main stream system. Therefore, an important task would be to review all the assumptions made about water use and availability in the closed basins, with a view to eliminating these data from the data base where appropriate. The actual designation of closed drainage basins was effected in Phase IV, based on standard mapping and previous studies, but if improved information were available then this should be obtained and applied.

(d) Small Subbasins

It has been commented in this and previous phases that the WUAM and its data base may not be fully appropriate for investigating water supply constraints at the level of small subbasins. While the model is conceptually capable of assessing small subbasins, a high and reliable degree of accuracy cannot be achieved in estimating small data values from regionally aggregated or average data. Therefore, it may be desirable to include these small subbasins within their corresponding main stream basins in future modeling of the system. This approach would be more compatible with the intended regional and interjurisdictional nature of the required modeling capability.

(e) Groundwater

Additional data on groundwater supply availability and use is required if the model capabilities for the simulation of groundwater are to be enhanced. This should include information on aquifers and the users who rely on groundwater supplies.

(f) Water Quality

Base line data will be required to develop the water quality modeling capabilities. This will include sources of effluents, their nature and information on the major quality constituents currently transported. Information will also be required to predict changes in effluent loadings for the future scenarios.

5.3 - Applications

(a) Reservoir Operating Policies

Work on the Waterton and St. Mary Reservoirs in this phase has illustrated the impact that alternative reservoir operating policies can have on the simulation results. Operating policies used for the reservoir simulate the current reservoir regulation. A study could be undertaken to illustrate the effect that alternate reservoir operating policies could have on water availability. Changes in target outflows or rule curve levels could have a significant impact on shortages in the subbasins.

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